UPPER CAMBRIAN AND BASAL ORDOVICIAN TRILOBITES FROM WESTERN NEW SOUTH WALES

by B. D. WEBBY, WANG QIZHENG *and* K. J. MILLS

Abstract. Eleven trilobite species are described from the Upper Cambrian–basal Ordovician succession exposed to the south-eastern side of Koonenberry Mountain in western New South Wales. Included among the forms are six new species, *Rhaptagnostus leitchi*, *Pareuloma aculeatum*, *Pseudoyuepingia whitei*, *P. lata*, *Proceratopyge ocella*, and *Hysterolenus furcatus*. The assemblages come from two stratigraphically distinct horizons near the top of the Watties Bore Formation. The lower has the more diverse fauna with typical Upper Cambrian elements such as *Rhaptagnostus*, *Pseudoyuepingia*, *Proceratopyge*, *Hedinaspis*, and *Prosaukia*? The upper horizon contains *Hysterolenus* usually taken as an indicator of a restricted early Tremadoc age. There are no apparent lithological or physical breaks in the intervening barren, conformable, 100 m thick siltstone and shale succession, and it probably spans the Cambrian–Ordovician boundary. Both assemblages are preserved in silty shaly beds, and are characteristic elements of a deeper, basinal, or slope-type biofacies. Genera such as *Pseudoyuepingia*, *Hedinaspis*, *Pareuloma*, and *Hysterolenus* are not known from shallow platform successions elsewhere in Australia but occur in equivalent biofacies of Chinese sequences. The common occurrences suggest close zoogeographic links. Similar though less strong connections are suggested with other circum-Pacific regions, in particular with Alaska and New Zealand.

Cambrian trilobites have been described from a number of localities and horizons in western New South Wales (text-fig. 1), in particular from the late Early–Middle Cambrian successions of the Mount Wright area by Öpik (1967*a*, 1970, 1975*a*, *b*, 1979, 1982), Shergold (1969), and Jell (1975) and from the Upper Cambrian (Mindyallan-Idamean) deposits of the Kayrunnera–Cupala Creek region by Öpik (1975*b*) and Jell (*in* Powell *et al.* 1982). Öpik (1975*b*) listed a Mindyallan fauna from Kayrunnera as including *Aguostoglossa*, *Palaeodotes*, *Blackwelderia*, *Ascionepea*, *Aulacodigma*, and *Meteoraspis*, and Jell (*in* Powell *et al.* 1982) described an Idamean assemblage from the upper part of the Cupala Creek Formation as comprising *Pseudagnostus* aff. *idalis* Öpik, 1967*b*, *Stigmatoa tysoni* Öpik, 1963, *Aphelaspis*? aff. *australis* Henderson, 1976, *Notoaphelaspis orthocephalis* Jell, 1982, and *Prismenaspis*? sp.

Still younger assemblages are described herein from the Watties Bore Formation to the south-east of Koonenberry Mountain (text-figs. 1 and 2). They comprise a latest Cambrian association (locality 1 at grid reference 277-205, text-fig. 1) including *Micragnostus* sp., *Rhaptagnostus leitchi* sp. nov., *Pareuloma aculeatum* sp. nov., *Hedinaspis* sp., *Prosaukia*? sp., *Pseudoyuepingia whitei* sp. nov., *P. lata* sp. nov., *Proceratopyge ocella* sp. nov., and *P.* sp., and an earliest Ordovician occurrence (locality 2 at grid ref. 276-206, see text-fig. 1) of *Hysterolenus furcata* sp. nov.

STRATIGRAPHIC RELATIONSHIPS

E. C. Leitch found the first trilobites in weakly cleaved green-grey shales near Watties Bore, at the south-eastern end of Koonenberry Mountain (grid ref. 286-185, text-fig. 1), in May 1983. Subsequently one of the authors (K.J.M.) made further discoveries especially at two localities on the lower, eastern slopes of Koonenberry Mountain (grid refs. 277-205 and 276-206, text-fig. 1). The mapping of this Koonenberry–Wonnaminta region, completed in 1986, established the following stratigraphic relationships. First, the trilobite-bearing sequence was shown to have an exposed, unconformable base in Morden Creek. Secondly,

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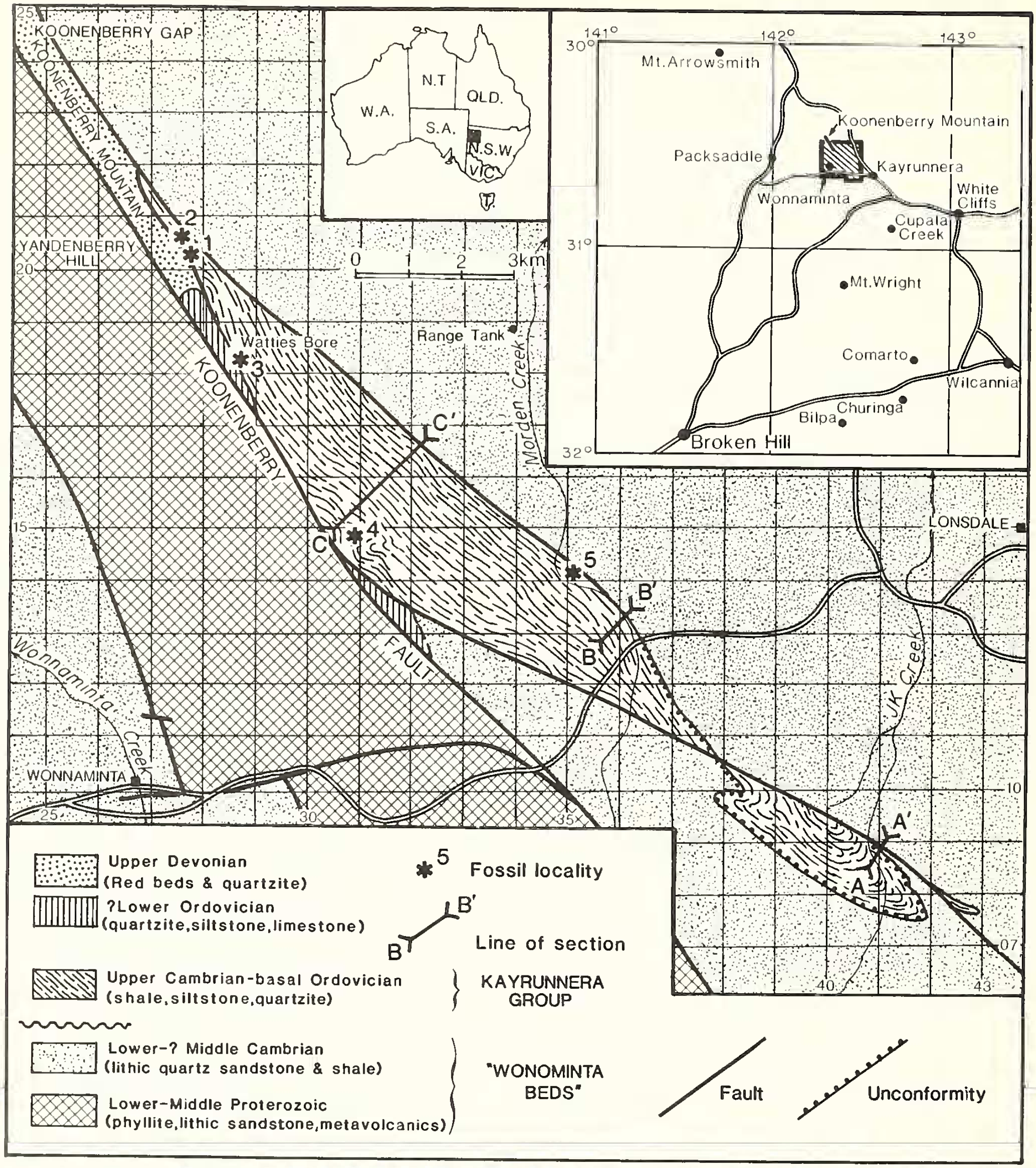
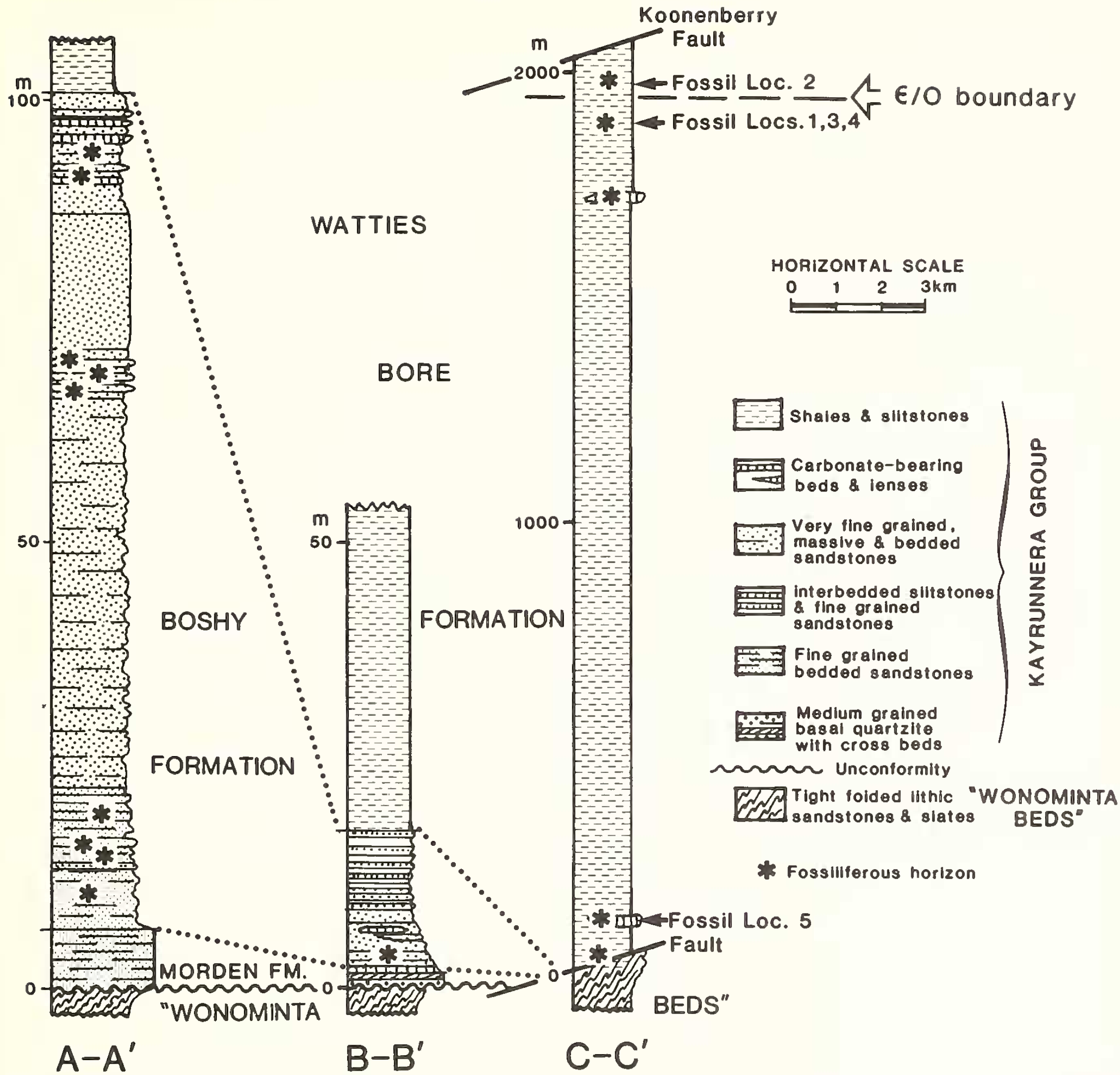


TEXT-FIG. 1. Geological map of the Koonenberry–Wonnaminta area and inset locality maps of far western New South Wales, and Australia, to show location of the trilobite collecting localities 1–5 and lines of section A–A′, B–B′, and C–C′. Note that the km² grid is based on the universal grid presented on the 1:100000 orthophotomap no. 7336 (Wonnaminta), First Edn., 1978.



TEXT-FIG. 2. Stratigraphic columns of sections through the Kayrunnera Group (Upper Cambrian–basal Ordovician) at Boshy Creek (A–A′) and at Morden Creek (B–B′) and near Watties Bore (C–C′). Note the relationship between the three formations of the Kayrunnera Group, and the stratigraphical positions of the collecting localities 1–5 within the Watties Bore Formation. Note the position of the Cambrian–Ordovician (∈/O) boundary.

the lower part of the sequence was found to be laterally equivalent to the Upper Cambrian (Mindyallan) trilobite-bearing beds recorded by Öpik (1975*b*) from Kayrunnera, some 16 km to the south-east. Thirdly the new trilobite finds described here were established as coming from the uppermost part of the sequence, from the upper part of the Watties Bore Formation (localities 1 and 2, text-figs. 1 and 2).

In the Koonenberry–Wonnaminta area the shale-dominated, trilobite-bearing sequence occupies a large, lens-shaped sliver to the east and south-east of Koonenberry Mountain (text-fig. 1). It is bounded by near vertical faults including the main line of the Koonenberry Fault south of Watties Bore (text-fig. 1), with only the base of the sequence seen to overlie unconformably lithic sandstones of the 'basement' succession in the vicinity of Morden Creek (grid ref. 362-132). These latter deposits are possibly of early–?middle Cambrian age. In continuity with this large, faulted sliver is another to the south-east, extending off the mapped area shown in text-fig. 1, towards Kayrunnera station. The lower, more sandy part of the trilobite-bearing sequence is best exposed near Kayrunnera, where it was first discovered and mapped by the Geological Survey of New South Wales in 1963 (Rose *et al.* 1964; Rose 1974). Again the sequence was observed to overlie unconformably the older basement. The Mindyallan trilobites identified by Öpik (1975*b*) come from this basal part of the sequence. Brunker *et al.* (1971) referred informally to the sequence as the 'Kayrunnera Beds'. It is here proposed to formalize this name as the Kayrunnera Group and to incorporate all the Upper Cambrian–basal Ordovician fossiliferous sequences from Kayrunnera to the eastern side of Koonenberry Mountain in this unit.

Kayrunnera Group

The greatest thickness of the Kayrunnera Group, over 2000 m of dominant shale and siltstones, is preserved in the Koonenberry–Wonnaminta area. The steeply dipping and west-facing sequence is essentially homoclinal, although some relatively open folds have been found near the top of the sequence around grid ref. 310-145 (text-fig. 1). Bedding laminations, bands, and units are well preserved in most outcrops. The degree of metamorphism is slight (chlorite zone) but a near-vertical slaty cleavage trending about 120° is a prominent feature of the silty and shaly lithologies, and pencil cleavage results from the intersection of this cleavage with bedding laminations. Although white quartz veins are an ubiquitous feature of the underlying basement units, they are very rarely observed within the Kayrunnera Group. Over most of the mapped area of the Kayrunnera Group shown in text-fig. 1 the scattered exposures of siltstones and shales are deeply weathered to orange, yellow, and cream colours. Some of the better and fresher exposures occur in the higher ground around Watties Bore and adjacent to the southern end of Koonenberry Mountain, where the freshest rocks are green-grey.

On the basis of the detailed mapping the Kayrunnera Group can be divided into three formations as follows:

Morden Formation. A thin (1–6 m) medium-grained pure quartzite forms a remarkably persistent basal unit of the Kayrunnera Group over the 16 km length of mapped unconformity between Morden Creek (text-fig. 1) and Kayrunnera homestead. A calcareous cement may be found in places in the upper part of the unit, and small to medium cross-beds are not uncommon and reveal a south-easterly current source. The formation was first recognized, and a type section measured, in the bed of Morden Creek (grid ref. 362-132, text-figs. 1 and 2) where a 2 m thick quartzite bed can be seen to overlie unconformably isoclinally folded lithic sandstones. This locality is designated as the type section of the Morden Formation. The underlying sandstones are thought to be of early–?middle Cambrian age on the basis of lithological correlation with the Copper Mine Range Beds (Pogson and Scheibner 1971), which contain sponge spicules and trace fossils (Leitch *et al.* 1987) in an area near Cupala Creek about 40 km to the south-east.

Boshy Formation. This formation consists of interbedded fine-grained sandstones and siltstones with some calcarenites and limestone lenses. Some horizons are richly fossiliferous and the Mindyallan trilobites identified by Öpik (1975*b*) come from this unit. The formation is named after Boshy Creek, 4 km south-east of the type section on a tributary of JK Creek between grid ref. 410-089 to 409-089 (text-figs. 1 and 2) where 94·3 m of section is preserved. Another measured section is in Morden Creek (text-fig. 2) but here the Boshy Formation is only 15·7 m thick. This section is very weathered; the lower 5·2 m consists of fine-grained bedded quartz sandstones and the remaining 10·5 m consists of fine-grained well-bedded sandstone interbanded with siltstones.

Watties Bore Formation. Some 2000 m of shales and siltstones, with a distinctive yellow-buff weathering characteristic, conformably overlie the Boshy Formation. Some levels are well bedded with interleaved shales and siltstones while other levels are more massive. The formation is named after Watties Bore (grid ref. 286-185, text-fig. 1) where good exposures occur. The type section is represented along the line of section C–C′ on text-fig. 1 (grid refs. 321-167 to 304-148). Of the five fossil localities shown in text-fig. 1, assemblages from localities 1 and 2 (grid refs. 277-205 and 276-206) are the best preserved and the basis for the present descriptions (see above cited list of species). Others comprise occurrences of *Pseudoyuepingia* sp. and *Proceratopyge*? sp. first found by E. C. Leitch near Watties Bore (locality 3, text-fig. 1), and *Pseudoyuepingia whitei* sp. nov. and *P. lata* sp. nov. from a creek section at grid ref. 308-147 (locality 4, text-fig. 1).

Some very fine-grained sandstones and siltstones interbedded in the shale sequence display occasional cross-bedding and slumping indicating a south to north palaeoslope. Calcareous concretions occur within some siltstone beds and these record flattening associated with tectonic deformation. Ellipsoidal concretions up to 250 mm in length have been noted around grid ref. 349-141 (text-fig. 1). Well bedded and laminated impure shaly limestones are also found in some exposures, with a few containing indeterminate agnostid and polymerid trilobite and brachiopod casts, such as at locality 5 (grid ref. 347-144, text-fig. 1).

Several limestone breccia lenses, representing channel deposits, are found within the shaly siltstone sequence around grid ref. 281-202 (text-fig. 1). The largest lens is 10 m long and up to 1 m thick. It contains a mixture of rounded to subangular and irregular limestone clasts to 200 mm in diameter and sub-rounded to subangular lithic sandstone boulders to 100 mm diameter. The limestone clasts are of several lithological types and some contain fossil fragments. Some clasts are micritic and others calcarenitic, with up to 50% rounded and polished quartz grains. The matrix of the breccia is a silty shaly limestone with abundant angular hard siltstone fragments. Some limestone clasts contain simple protoconodonts of Upper Cambrian type.

Correlatives of the Kayrunnera Group. The 1000 m thick Cupala Creek Formation cropping out some 40 km to the south-east (Powell *et al.* 1982) appears to represent an onshore (upslope) equivalent of the Kayrunnera Group succession. It was derived from the south, and comprises an upwardly fining transgressive sequence commencing in fluvial conglomerate and sandstone depositional phases and passing up through marginal marine sandy to shallow marine silty deposition towards the top. The Idamean faunas recorded by Jell (*in* Powell *et al.* 1982) are restricted to the upper part of the sequence. It seems likely that the shallow-marine Morden and Boshy Formations of Mindyallan age are equivalent to the fluvial to marginal marine lower–middle parts of the Cupala Creek Formation, and the deeper marine lower part of the Watties Bore Formation is correlative with the shallow-marine upper part of the Cupala Creek Formation of Idamean age. The deeper marine upper part of the Watties Bore Formation of latest Cambrian to earliest Ordovician age is not represented by equivalent, preserved deposits in the Cupala Creek area.

AGE AND ZOOGEOGRAPHIC SIGNIFICANCE

Of the two stratigraphically distinct trilobite assemblages documented from the upper part of the Watties Bore Formation, the lower, with its diverse association of *Micragnostus* sp., *R. leitchi* sp. nov., *Pareuloma aculeatum* sp. nov., *Hedinaspis* sp., *Prosaukia*? sp., saukiid gen. et sp. indet.?, *Pseudoyuepingia whitei* sp. nov., *P. lata* sp. nov., *Proceratopyge ocella* sp. nov., and *P.* sp., is characteristically an Upper Cambrian fauna. *Hedinaspis* and *Pseudoyuepingia* are genera with ranges limited to the Upper Cambrian, *Proceratopyge* has a Middle–Upper Cambrian range, and *Pareuloma* an Upper Cambrian to lowest Ordovician (Tremadoc) range. The upper horizon is only about 100 m stratigraphically above the lower horizon, and contains *Hysterolenus furcatus* sp. nov. This genus *Hysterolenus* is usually regarded as an indicator of the lowest part of the Ordovician (Shergold 1988; see also later discussion of the genus). Judging from the uniformity of the green-grey silty shale lithology at the two horizons and through the intervening sequence there is no evidence for associated breaks or unconformable relationships. Consequently the lower diverse fauna is at least post-Idamean, probably middle–Late Cambrian in age.

This Cambrian–Ordovician boundary succession with its accompanying faunas is most closely comparable to a number of sections described from south-east China, as well as to sections in parts of north-west and north China. For example, in the Duibian area of Jiangshan, eastern Zhejiang Province, a Cambrian–Ordovician boundary section is recorded by Lu *et al.* (1984) as exhibiting species of *Hedinaspis*, *Pseudoyuepingia*, and *Proceratopyge* in beds 1–2 of the Siyangshan Formation (*Hedinaspis* subzone of the *Lotagnostus punctatus* Zone) and then about 45 m stratigraphically higher, occurrences of *Hysterolenus* in the basal Yinchupu Formation (*Hysterolenus* Zone). In this particular section the intervening sequence includes rich trilobite and cephalopod faunas attributed to the *Lophosaukia* subzone, the *Acaroceras–Antacaroceras* Zone, and the *Lotagnostus hedini* Zone of the latest Cambrian. None of these faunal elements have yet been found in the 100 m thick intervening succession in western New South Wales. Similarly, in the Cambrian–Ordovician boundary section through the Guotang Formation in Sandu county in Guizhou Province, Yin *et al.* (1984) have reported species of *Hedinaspis* and *Pseudoyuepingia* as occurring in the topmost beds of the Cambrian, less than 2 m below the first record of *Rhabdinopora flabelliformis* (the subspecies *regularis*) and about 6–7 m below the first occurrence of *Hysterolenus* in the basal Ordovician beds. In the Hangula region of Nei Monggol, north China, a Cambrian–Ordovician boundary has been drawn by Lu *et al.* (1981) between the *Hedinaspis–Diceratopyge* and the *Hysterolenus* assemblages.

Lu *et al.* (1984) have stressed the pattern of incomings of typical Early Ordovician graptolite assemblages as occurring above the *Hysterolenus* Zone in south-east China but, like its occurrences in Scandinavia in association with dendroid graptolites of the *Dictyonema* Shale (Bergström 1982), *Hysterolenus* has also been recorded as mainly occurring with *R. flabelliformis* (*s.l.*) in Taoyuan of north-west Hunan and Sandu of south-east Guizhou Provinces in south-east China (Lu *et al.* 1984). The conodont index *Cordylodus proavus* is recognized as appearing just before *Hysterolenus* in the Cambrian–Ordovician boundary section in the Duibian area of western Zhejiang Province (Lu *et al.* 1984), that is, in beds of the latest Cambrian (*L. hedini* Zone). Similar assignments of *C. proavus* as spanning the boundary have been demonstrated in other Chinese sections, in north-west Hunan Province (Peng 1984) and in north-east China (Zhou *et al.* 1984; Wang 1984).

There is little similarity between these Cambro-Ordovician trilobite assemblages from the deeper, shaly, basinal Watties Bore Formation of western New South Wales and age equivalents from the shallow carbonate successions of continental platform areas of Australia. The post-Idamean Late Cambrian–earliest Ordovician interval has been subdivided into numerous zones based on sections in the platform carbonates of the Georgina Basin of western Queensland (Jones *et al.* 1971; Shergold 1975, 1980) but they cannot be applied in correlation of the western New South Wales basinal deposits. As a member of the *Rhaptagnostus convergens* species group, the occurrence of *R. leitchi* sp. nov., may suggest a pre-Payntonian age for the lower assemblage, that is, between the Zones of *Neoagnostus denticulatus* and *R. papilio* of Shergold (1975). Also the presence of a few saukiids may suggest a level in the upper pre-Payntonian or Payntonian, but a closer correlation is not presently achievable. The *Hysterolenus* horizon is best assumed to approximate to a level within the Datsonian of Jones *et al.* (1971).

The Watties Bore faunas of western New South Wales comprise several dominantly 'Chinese' genera such as *Pseudoyuepingia* and *Hedinaspis*, but also other ceratopygacean elements of more general Asian and European affinities like *Proceratopyge* and *Hysterolenus*. They clearly have closest connections within the South-east China Faunal Province of Lu *et al.* (1974, 1984), which includes much of south-east China (geographical provinces of Zhejiang, Anhui, Hunan, and Guizhou) and extends to north and north-west China (Nei Monggol, Qinghai, and Xinjiang), even to southern Kazakhstan (Shergold 1988). However, what is referred to as the South-east China Faunal Province is perhaps better viewed as an off-shelf or open-ocean facing biofacies whose distribution, which is dominantly of ceratopygaceans, has a much wider geographical extent, being recorded as peripheral to the shallower (colder?) olenid biofacies of the Baltic Faunal Province, and to the shallower (warmer?) biofacies of North China Faunal Province type on the North China Platform and Australian Platform (Shergold 1988).

This off-shelf biofacies with, for instance, its records of *Hedinaspis*, extends to include parts of South Korea (Kobayashi 1966), the west coast of North America, particularly Alaska and Nevada (Taylor 1976), to Australia including western New South Wales (described herein) and Tasmania (Jago, *in* Shergold *et al.* 1985; Jago 1987), and to New Zealand (Wright and Cooper 1983). *Pseudoyuepingia* has a more restricted distribution in south-east and north-west China, South Korea, Tasmania, and western New South Wales, but earliest Ordovician *Hysterolenus* (= *Ruapyge*) has a similarly wide spread of occurrences, in New South Wales, New Zealand, north-north-west and south-east China, Kazakhstan, the Soviet Altai, Baltoscandia and, possibly, an earlier occurrence in North Wales. *Pareuloma* is also represented mainly in the Upper Cambrian of China and New South Wales, though there are other occurrences in Alaska, and an earliest Ordovician record of the genus from Newfoundland.

Only the agnostid genera, the saukiids, and *Proceratopyge* are also known from platform successions of Australia. However, the species of *Proceratopyge* from western Queensland (Henderson 1976; Shergold 1982) are from older (Idamean) horizons and are morphologically markedly distinct. Shergold (1988) has noted that the Australian Platform, extending to northern Victoria Land, Antarctica, should be included within the North China Faunal Province. It is dominated by saukiid and tsinaniid trilobites like the assemblages found in the platform areas of western Queensland, central Australia, and the Mount Wright area of western New South Wales (Shergold 1971*a*; Shergold *et al.* 1982). These are on-shelf siliciclastic and carbonate associations of north China type. In contrast the saukiids are poorly represented in the off-shelf assemblages of the Watties Bore Formation in the Koonenberry–Wonnaminta area of western New South Wales (text-fig. 1).

This Watties Bore section is important in providing the first documentation of the ceratopygacean-dominated off-shelf biofacies of the South-east China Faunal Province through the Cambrian–Ordovician boundary interval of the Australian region. Elements of this biofacies have potential for correlation in fold-belt regions of the circum-Pacific and in parts of central and south-eastern Asia (particularly in China, Kazakhstan, and the Soviet Altai).

SYSTEMATIC PALAEONTOLOGY

Type specimens are housed in the palaeontology collection of the Department of Geology and Geophysics, University of Sydney, and have the prefix SUP. Two of the authors (B. D. W. and W. Q.) are responsible for the trilobite descriptions.

Order MIOMERA Jaekel, 1909
Suborder AGNOSTINA Salter, 1864
Family AGNOSTIDAE M'Coy, 1849
Subfamily AGNOSTINAE M'Coy, 1849
Genus MICRAGNOSTUS Howell, 1935

Type species. Agnostus calvus Lake, 1906.

Discussion. Fortey (1980) clarified relationships between the Upper Cambrian–Lower Ordovician agnostid genera *Micragnostus* Howell, 1935 and *Geragnostus* Howell, 1935. He established that a number of North American and Chinese species assigned previously to *Geragnostus* should be referred to *Micragnostus*. The genus *Micragnostus* is regarded by Fortey (1980) as belonging in a conservative plexus with Upper Cambrian *Agnostus* Brongniart, 1822 and *Homagnostus* Howell, 1935, with *Micragnostus* seen as likely to be in direct line of descent from *Homagnostus* (see also Robison and Pantoja-Alor 1968).

Micragnostus sp.

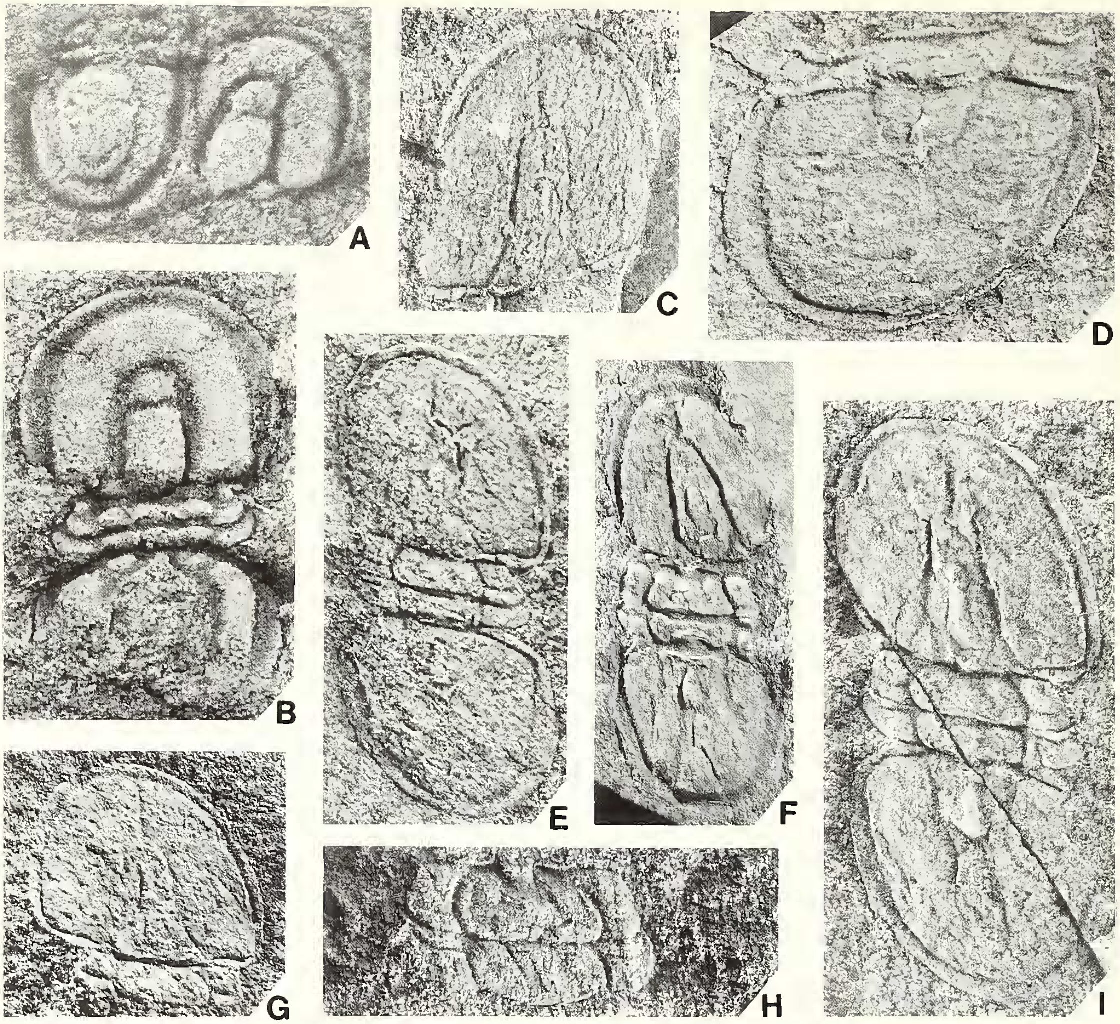
Text-fig. 3A, B

Material. Two specimens (SUP 48900–48901) from the lower horizon (locality 1) in the upper part of the Watties Bore Formation on the eastern side of Koonenberry Mountain, western New South Wales.

Description. Specimens partially damaged internal moulds attaining length of about 6 mm (sag.). Cephalon gently convex, with its maximum width near mid-length. Glabella subcylindrical in outline with slight forward taper, defined by deep, broad axial furrows; approximately 0·60 of total cephalic length (sag.); deep transverse glabellar furrow divides small anterior lobe from larger posterior lobe; the latter with faint median glabellar node situated just behind mid-point (sag.). Small, triangular basal lobes. Cheeks moderately convex, with no trace of median furrow on preglabellar field; outlined by deep and very wide anterior and lateral border furrow; posterior border furrow much narrower (exsag.).

Thorax of relatively narrow (sag.) segments; axis as broad (tr.) as glabellar base; axial ring broad, evenly divided into convex median, and lateral lobes. Pleura relatively narrow (tr.), the second being longer (tr.) than the first.

Pygidium moderately convex, subquadrate with broadly rounded posterior margin. Axis relatively broad (tr.) and long, about 0·5 of total width and 0·75 of pygidial length (sag.). First axial ring divided into a pair of lateral lobes, each with transversely ovoid outline, and a median area which is a forward, tongue-like extension of larger triangular median lobe (which includes second axial ring); only broken base of median



TEXT-FIG. 3. A–B, *Micragnostus* sp., Watties Bore Formation, uppermost Cambrian, ×10. A, internal mould of SUP 48901 showing cephalon detached from thorax and pygidium; B, internal mould of cephalon, thorax, and incomplete pygidium, SUP 48900. C–H, *Rhaptagnostus leitchi* sp. nov., Watties Bore Formation, uppermost Cambrian. C, internal mould of incomplete cephalon of paratype, SUP 48909, ×5; D, internal mould of pygidium of paratype, SUP 48908, ×8; E, internal mould of complete dorsal exoskeleton of paratype, SUP 48904, ×5; F, internal mould of complete exoskeleton of holotype, SUP 48905, ×7; G, internal mould of cephalon and incomplete thorax of paratype, SUP 48902, ×5; H, internal mould of thorax of paratype, SUP 48906, ×8; I, *Rhaptagnostus leitchi* sp. nov.?, Watties Bore Formation, uppermost Cambrian; internal mould of complete dorsal exoskeleton of specimen, SUP 48910, ×5.

tubercle vaguely shown towards rear margin of median lobe. Relatively large terminal piece, about twice sagittal length of anterior two axial segments. Pleural fields narrow, slightly wider anterolaterally.

Remarks. This species is closely similar to *M. intermedius* (Palmer 1968) from the Upper Cambrian of Alaska and Tremadoc of Mexico (Robison and Pantoja-Alor 1968), differing only in details such as lack of a median furrow on the preglabellar field and apparent lack of posterolateral border spines on the pygidium. Another closely related species is assigned to *Homagnostus*, as *H.*

zhuangliensis Qian, 1985 from the latest Cambrian Tangcun Formation of Jingxian, southern Anhui Province, China. It is described as lacking a preglabellar median furrow and exhibiting at least in one pygidium (Qian 1985, pl. 1, fig. 11) a less expanded pygidial axis than typically found in *Homagnostus*. The species should instead be assigned to the genus *Micragnostus*. It only differs from *M*. sp. in showing a slightly more elongated (sag.) cephalon and having the faint median tubercle nearer to the mid-point (sag.) on the posterior lobe of the glabella.

Of the Australian species of the genus, it most resembles *M*. cf. *intermedius* (Palmer 1968) from the Upper Cambrian Chatsworth Limestone of Black Mountain, western Queensland (Shergold 1975), but has a broader cephalic border furrow and lacks the faint median preglabellar furrow. It also differs from *M. acrolebes* (Shergold 1971*b*) from the Upper Cambrian Gola Beds of western Queensland in lacking traces of anterolateral glabellar lobes, and in having a pygidium with relatively wider axis, narrower border, and lacking posterolateral border spines. *M. hoeki* (Kobayashi 1939) from the Digger Island Formation (Lower Tremadoc) of Victoria (Jell 1985) has a relatively wider glabella, a trace of a medium preglabellar furrow adjacent to the glabella, prominent median node not far behind transglabellar furrow, and a pygidium with a relatively narrow axis, wider posterolateral border, and well-developed marginal spines.

Family DIPLAGNOSTIDAE Whitehouse, 1936, emend. Öpik, 1967*b*
Subfamily PSEUDAGNOSTINAE Whitehouse, 1936
Genus RHAPTAGNOSTUS Whitehouse, 1936

Type species. Agnostus cyclopygeformis Sun, 1924; designated by Whitehouse 1936.

Discussion. Shergold (1977, 1980) has discussed the status and subdivision of this pseudagnostinid genus. He recognized two species groups defined by *R. convergens* (Palmer 1955) and *R. clarki* (Kobayashi 1935). Both have widespread distribution in Upper Cambrian deposits of Australia, Asia (especially China), and North America. In western Queensland representatives of the *convergens* group are recorded from the pre-Payntonian *N. denticulatus* and *R. papilio* Assemblage Zones of Shergold (1975) and members of the *clarki* group from the pre-Payntonian *R. clarki maximus* to Payntonian *N. quasibilobus–Tsinania nomas* Assemblage Zones of Shergold (1975).

Rhaptagnostus leitchi sp. nov.

Text-fig. 3C–H

Material. Holotype (SUP 48905) and seven paratypes (SUP 48902–48904, 48906–48909) from the lower horizon (locality 1) in the upper part of the Watties Bore Formation, eastern side of Koonenberry Mountain, western New South Wales.

Etymology. After Dr E. C. Leitch who found the first trilobite sample in the area near Watties Bore in 1983.

Diagnosis. Member of the *R. convergens* species group (Shergold 1977, 1980) with a large and attenuated, bell-shaped glabella, and long (sag.) preglabellar field.

Description. Dorsal exoskeleton of mature specimens of relatively large size, from 12 to 15 mm in length and usually about 5 mm in width. All the material somewhat poorly preserved and compressed; a few specimens also tend to be a little distorted. Cephalon widest (tr.) along a transverse line just behind axial glabellar node. Glabella with bell-shaped outline, bounded by variably preserved, narrow axial furrows; about two-thirds length (sag.) of cephalon and nearly half maximum width of cephalon. Ill-defined anterior lobe of glabella occupies about one-third total glabellar length; a pair of oval-shaped anterolateral lobes separated from anterior lobe by faint V-shaped furrow and bisected adaxially by prominent ridge-like, backwardly directed axial glabellar node; weakly defined, large posterior lobe and a pair of moderate-sized triangular basal lobes at rear. Median preglabellar furrow almost continuous sagittally to anterior border furrow; preglabellar field relatively long (sag.), extending backwards and outwards into broad, flattened cheek regions; moderately deep, continuous cephalic border furrow, defining raised, narrow cephalic border.

First thoracic segment slightly better developed and longer (sag.); axis varies in width (tr.), owing to mainly zigzag course of axial furrow. Articulating furrow of first segment exhibits raised, median axial bar (text-fig. 3H). Pleura relatively narrow, with sharply rounded, backwardly turned tips; pleural furrow of second segment, in contrast to first segment, is placed close to anterior margin.

Pygidial axis lobate, with first two axial segments occupying about 0·4 of pygidial length (sag.), and axis about 0·3 of total width (tr.) at anterior margin; transverse furrow between first and second axial segments poorly defined, but with strong, raised axial node extending backwards and expanding slightly from point of origin near rear edge of first segment. Large third segment (or deuterolobe) not clearly outlined. Relatively deeply grooved (deliquiate of Shergold 1975) border furrows; border widening backwards into pair of very small posterolateral spines, then of more even width around posterior margin.

Remarks. Two additional specimens (SUP 48910 and 48911) of *Rhaptagnostus* from the same locality and horizon show the closest relationships, but differ in exhibiting deeper and broader axial and marginal furrows (text-fig. 3I). They may indeed represent the less effaced members of the species, but for the present should only be included tentatively in the species.

Order PTYCHOPARIIDA Swinnerton, 1915
Superfamily PTYCHOPARIACEA Matthew, 1887
Family PTYCHOPARIIDAE Matthew, 1887
Subfamily EULOMINAE Kobayashi, 1955
Genus PAREULOMA Rasetti, 1954

Type species. *Pareuloma brachymetopa* Rasetti, 1954.

Discussion. The eulominid genera are known to extend as a group from Franconian to Arenig age (Fortey 1983). Type species of the genus *Pareuloma*, *P. brachymetopa*, is recorded by Rasetti (1954) as coming from Cap des Rosiers, Quebec and Broom Point, Newfoundland. At Broom Point the type species and another, *P. impunctata* Rasetti, 1954, were apparently collected from the interval associated with occurrences of *Radiograptus* and *D. flabelliforme* close to the base of the Tremadoc (Fortey *et al.* 1982, fig. 1). Other species of *Pareuloma* have been recorded from the Upper Cambrian (Upper Franconian) beds of east-central Alaska (Palmer 1968), from the Upper Cambrian of Xinjiang and Qinghai provinces, China (Zhu 1979; Zhang 1981; Xiang and Zhang 1985), and from the Lower Ordovician of Salair in the Altai Sayan mountain region of the Soviet Union (Naletov and Sidorenko 1970).

Most authors have regarded *Pareuloma* as having separate generic status, but Sdzuy (1958) suggested it might be viewed as a subgenus of *Euloma* Angelin, 1854. As originally diagnosed by Rasetti (1954) the genus *Pareuloma* is distinguished by having a relatively smaller glabella with correspondingly wider fixed cheeks, and the presence of a much smaller, more anteriorly placed pair of palpebral lobes. The genus *Sanduspis* Chien, 1961 (type species, *S. gracilis* Chien, 1961) from the Upper Cambrian Sandu Formation of Guizhou Province—see also Yin and Li (also spelt Lee) 1978, p. 453, pl. 158, fig. 10—has similar features, only differing in its smaller size (possibly as an immature stage of growth), relatively larger glabella and more rounded, almost sharply rounded anterior margin, but these differences may not be truly diagnostic of a separate genus. Indeed, it may be best to regard *Sanduspis* tentatively as a junior synonym of *Pareuloma*. Another Chinese genus which appears to be quite closely related is *Chekiangaspis* Lu (type species *C. chekiangensis*, Lu). Lu *et al.* (1965, p. 178) have attributed this genus to a publication by Lu in 1960 but apparently the first description and illustrations in print are in Chien (1961, p. 103, pl. 4, figs. 11 and 12; pl. 5, figs. 8 and 9). This form, which is recorded by Yin and Li (1978, p. 476, pl. 162, fig. 4) from the Upper Cambrian Xiyangshan Formation of Jiangshan and Changshan, Zhejiang Province, has similar thoracic and pygidial features but differs in exhibiting a more transversely expanded cephalon, different proportions between fixed and free cheeks and less prominent lateral glabellar furrows. The fixed cheeks are narrower (tr.) and the eye ridges inconspicuous. The free cheeks are expanded anterolaterally and prolonged posterolaterally into large outwardly and backwardly directed genal spines.

Proteuloma Sdzuy, 1958 (type species, *Conocephalites geinitzi* Barrande, 1868) may also be compared with *Pareuloma*, especially since Xiang and Zhang (1985) have recently reassigned a number of species originally grouped in *Pareuloma* to this genus. The glabella of *Pareuloma* is, however, relatively much shorter, about half the length of the cranidium, the palpebral lobes are further forward, placed at the level of the anterior end of the glabella, the preglabellar field may, but does not always, show a gently raised medium boss, the posterior border furrow is deeper, and the pygidium more distinctly multisegmented.

Pareuloma aculeatum sp. nov.

Plate 83, figs. 1–13

Material. Holotype (SUP 48913) and fifteen paratypes (SUP 48912, 48914–48928) from the lower horizon (locality 1) in the upper part of the Wattics Bore Formation, eastern side of Koonenberry Mountain, western New South Wales.

Etymology. Latin *aculeatus*, spine-like, referring to long medial spines on the occipital ring and axis of the thorax.

Diagnosis. Species of *Pareuloma* with moderately elongate (sag.), forwardly tapering glabella, relatively narrow (sag.) preglabellar area with poorly differentiated median boss, small palpebral lobes, large macrospine on occipital ring, transversely elongated, somewhat flattened triangular pygidium with maximum width at level of first axial ring, terminal piece close to posterior border, weakly furrowed pleural fields, and a fine granulation.

Description. Exoskeleton of moderate size, usually from 20–40 mm in length (sag.), elongate-elliptical in dorsal outline and gently convex. Glabella with maximum width at level of occipital ring, being between 0·6 and 1·0 of glabellar length (sag.); width across base of glabella about one-quarter maximum width of cranidium. Two pairs of short, notch-like lateral glabellar furrows 1P and 2P at sides of glabella; 1P furrows more continuous, directed backwards and inwards, about half-way from occipital to 2P furrows; 2P furrow set approximately opposite rear end of palpebral lobe; trace of a 3P furrow seen in a few cranidia, placed near anterolateral corner of glabella. Occipital ring widening (exsag. and sag.) adaxially and posteriorly into base of large, straight, obliquely backwardly directed median macrospine, with separate median node set directly in front of spine. Preglabellar area extending to 0·6 of glabellar length (sag.); differentiated by deep and broad, anterior border furrow into extended gently convex (sag. and exsag.) area of preglabellar field and more sharply convex (sag. and exsag.) anterior border; small cranidia occasionally show small pits in anterior border furrow; median part of preglabellar field exhibits slighty updomed median boss.

Small arcuate palpebral lobe, placed opposite glabellar lobe 3P, with associated palpebral furrow extending into gently curved, forwardly convex eye ridge. Postocular cheek, large, and gently convex with maximum width greater than that of glabella; deep and wide posterior border furrow separates narrow border, which widens (exsag.) laterally, and then is deflected forwards and downwards posterolaterally. Course of preocular facial suture only slightly divergent in front of palpebral lobe, then curves sharply inwards along anterior edge of border. External surface covered with fine, close-spaced granules and scattered coarser granules especially in posteromedian corner of postocular cheek.

Free cheek relatively narrow (tr.), with lateral border evenly curved into long, backwardly, and slightly outwardly directed genal spine. Lateral border furrow deep and broad. Doublure, rostral plate, and hypostoma unknown.

Thorax of fifteen segments, approximately as wide as long; first six segments of similar length (tr.), then tapering progressively posteriorly. Axial rings of fourth to ninth segments have large, straight median macrospines, directed obliquely backwards and slightly upwards; traces of a small median tubercle may be seen on axial rings of first to third segments; transverse, slot-like apodemal pits set just inside deep axial furrows. Pleurae flattened, with first six pairs, especially the first three, exhibiting more sharply pointed, backwardly deflected spines, and more prominent triangular facets; the posterior pairs have shorter (tr.), more bluntly deflected tips. Pleural furrows broad (exsag.) and deep, with straight transverse course except for slight backward curvature of abaxial ends; usually placed towards centre (exsag.) of segment; tend to be pinched out well inside lateral margin of first five segments, but almost extend to tips of more posteriorly placed segments. Rows of coarse granules extend along anterior and posterior margins of pleural segments; a finer granulation covers entire surface of thorax; macrospines also show ornamentation of longitudinal furrows and fine granulation.

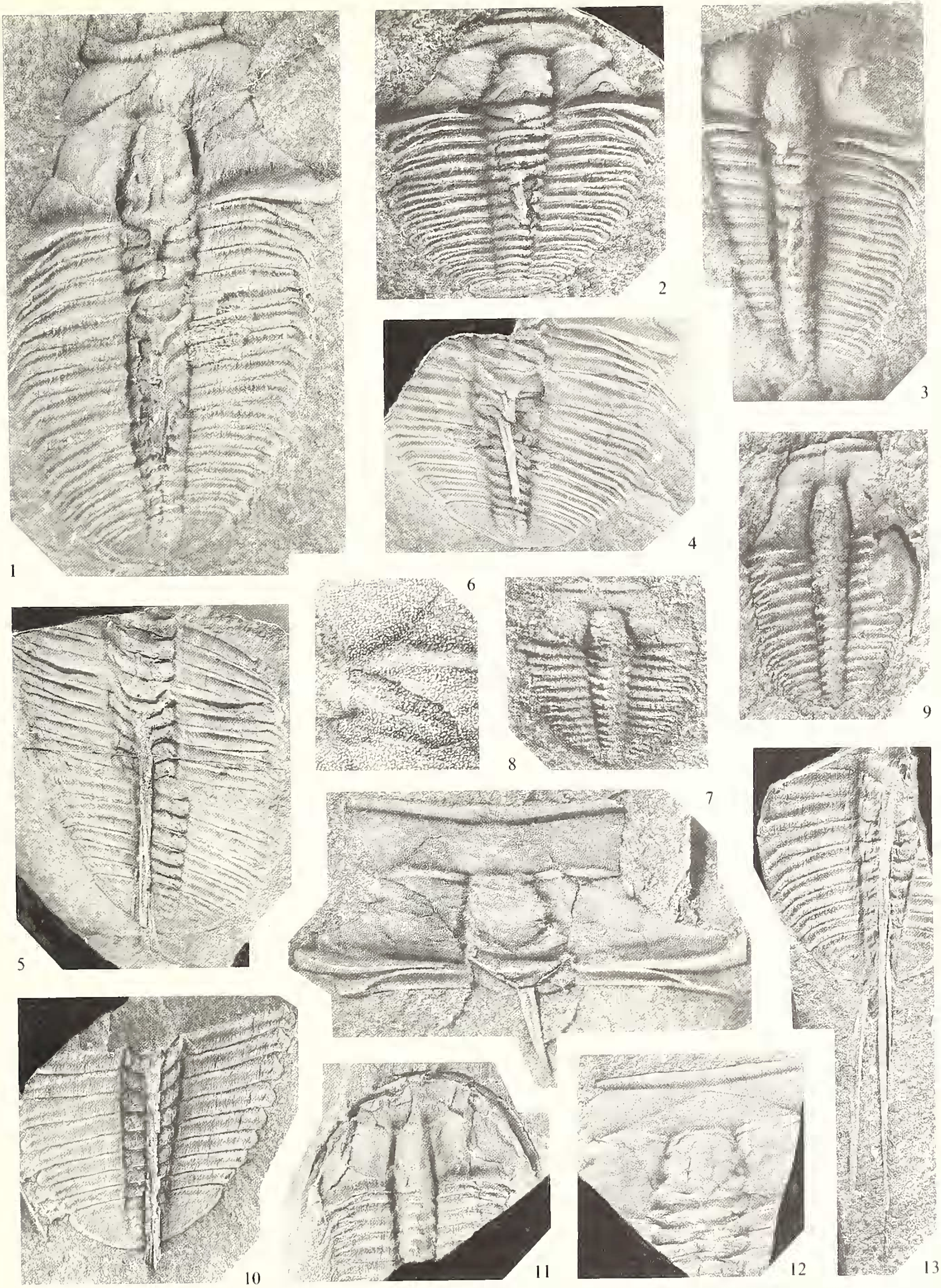
Pygidium small, subtriangular; about one-tenth of total length (sag.) of exoskeleton (excluding macrospines); length/width ratio varying from 0·3 to 0·4. Axis about one-quarter anterior width of pygidium, almost reaching posterior margin, and comprising up to four axial rings and a terminal piece; defined by shallow axial furrows which converge and weaken posteriorly. Pleural fields flat, with two pairs of broad (exsag.), shallow, transverse pleural furrows, the second pair being much less distinct. Border narrow with fine granules aligned in rows of wavy lines subparallel to margin. Surface ornamentation of fine and scattered coarser granules.

Remarks. *P. aculeatum* sp. nov., differs from the type species. *P. brachymetopa* Rasetti, 1954 from the basal Ordovician of Quebec and Newfoundland in having a slightly narrower (sag., exsag. and tr.) and less well differentiated, trilobed, preglabellar field, an occipital ring with large, backwardly directed, median macrospine, and flatter pygidium with less strongly furrowed pleural fields. The other Canadian species, *P. impunctata* Rasetti, 1954, has a poorly developed, unpitted anterior border furrow and relatively wider (sag. and exsag.) anterior border. Among the Upper Cambrian forms, the species *P. spinosa* Palmer, 1968 from the upper Franconian succession of east-central Alaska has the closest relationship. It has a closely similar cranidium, only differing from *P. aculeatum* in exhibiting larger palpebral lobes and a coarser external surface granulation. The pygidium is also comparable except that the terminal piece of the axis does not quite reach the posterior border as in *P. aculeatum*.

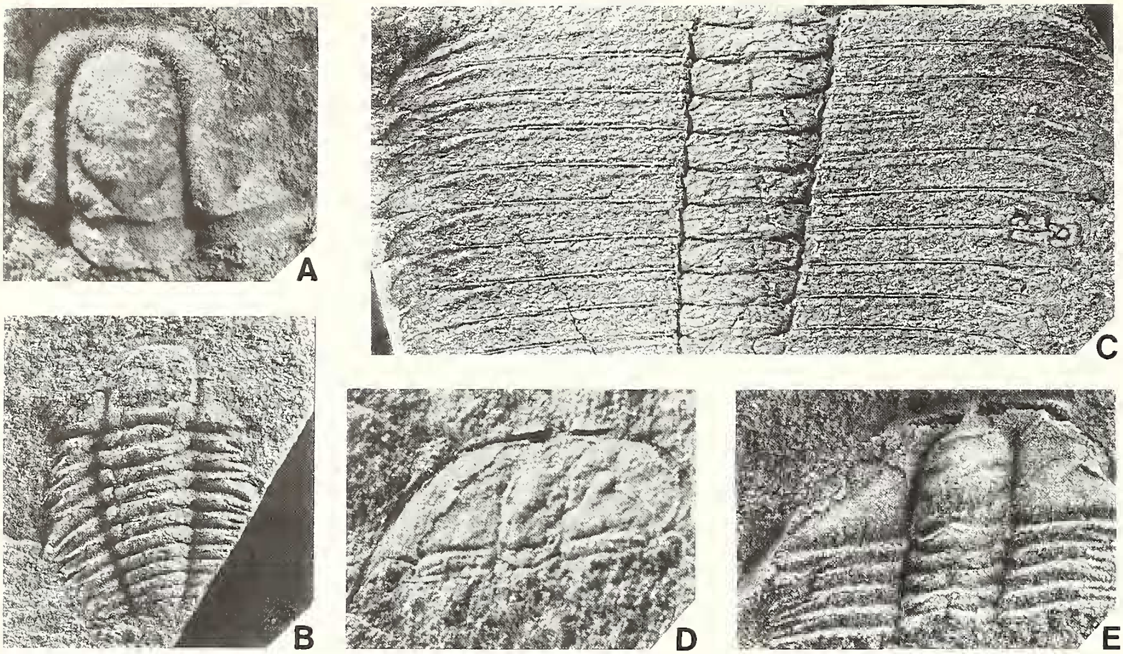
Of the Upper Cambrian species of *Pareuloma* from China only *P. huochengensis* Zhang, 1981 from the Guozigou Formation of Guozigou, Huoching County, Xinjiang Autonomous Region, shows a close resemblance. However, it has larger palpebral lobes, lacks a large macrospine on the occipital ring and has a less markedly transverse elongated, triangular-shaped pygidium with the maximum width of the pygidium behind the anterior margin, at the level of the second axial ring. Another Chinese species, *P. qinghaiensis* Zhu, 1979, from the Lindaogou Group of Angshidogou, southern side of Nidanshan mountain, in the Lajishan region of Hualong County, Qinghai Province, has a much broader (sag. and exsag.) preglabellar field, markedly shorter (sag.) and a more quadrate-shaped glabella. Xiang and Zhang (1985) have recognized other species which seem to be closely related, but have chosen to assign them to the genus *Proteuloma* (see previous discussion). Their main justification for reassigning such forms as *P. houchengensis* Zhang, 1981 and part of *P. spinosa* Palmer, 1968 to *Proteuloma* is apparently that they do not exhibit a median boss on the preglabellar field. Otherwise they are closely similar. Indeed, it seems that the subdivision is excessively arbitrary, especially Palmer's *P. spinosa* being split into two separate genera and species.

EXPLANATION OF PLATE 83

Figs. 1–13. *Pareuloma aculeatum* sp. nov., Watties Bore Formation, uppermost Cambrian. 1, latex cast of external mould of cranidium, thorax and pygidium of holotype, SUP 48913, ×4. 2, latex cast of external mould of cranidium, thorax, and pygidium of paratype, SUP 48915, ×5. 3, latex cast of external mould of incomplete dorsal exoskeleton of paratype, SUP 48916, ×5. 4, latex cast of external mould showing part of the cranidium attached to a complete thorax and pygidium, paratype, SUP 48921, ×3. 5, latex cast of external mould of incomplete thorax and pygidium of paratype, SUP 48919, ×2. 6 and 7, latex cast of external mould of cranidium of paratype, SUP 48922. 6, detail of granulation in the vicinity of the eye ridge, ×8. 7, general dorsal view, ×4. 8, internal mould of almost complete dorsal exoskeleton in meraspid stage, paratype, SUP 48917, ×8. 9, internal mould of near complete dorsal exoskeleton of late meraspid stage, paratype, SUP 48918, ×6. 10, latex cast of external mould of incomplete thorax and pygidium of paratype, SUP 48925, ×2. 11, internal mould of cephalon and incomplete thorax of paratype, SUP 48920, ×3. 12, internal mould of incomplete cranidium and thorax of paratype SUP 48914, ×3. 13, latex cast of external mould of incomplete thorax and pygidium of paratype, SUP 48924, showing large median macrospines, ×3.



WEBBY, WANG and MILLS, *Pareuloma*



TEXT-FIG. 4. A, *Prosaukia*? sp., Watties Bore Formation, uppermost Cambrian. Internal mould of cranidium of specimen, SUP 48930, ×10; B, saukiid? gen. et sp. indet., Watties Bore Formation, uppermost Cambrian. Internal mould of incomplete cranidium and thorax of specimen, SUP 48934, ×5; C, *Hedinaspis* sp., Watties Bore Formation, uppermost Cambrian. Internal mould of incomplete thorax of specimen, SUP 49938, ×3; D, *Hedinaspis* sp., Watties Bore Formation, uppermost Cambrian. Internal mould of cephalon and incomplete thorax of early meraspid stage, specimen SUP 49935, ×10; E, *Hedinaspis*? sp., Watties Bore Formation, uppermost Cambrian. Internal mould of incomplete cephalon and thorax of ?late meraspid stage, specimen SUP 49933, ×10.

Superfamily DIKELOCEPHALACEA Miller, 1889
Family SAUKIIDAE Ulrich and Resser, 1930
Genus PROSAUKIA Ulrich and Resser, 1933

Type species. *Dikelocephalus misa* Hall, 1863.

Prosaukia? sp.

Text-fig. 4A

Material. One cranidium (SUP 48930) from the lower horizon (locality 1) in the upper part of the Watties Bore Formation, eastern side of Koonenberry Mountain, western New South Wales.

Description. Small cranidium with subquadrate outline except for slightly extended posterolateral extremities. Glabella rectangular with rounded anterior margin; maximum width 0·5 of sagittal glabellar length. Two (possibly three) pairs of transglabellar furrows; first pair deeply impressed abaxially, deflected backwards and inwards at about 45° to exsagittal line, to mid-point (tr.) on occipital furrow thus delimiting pair of triangular 1P lobes, but also with gently inward curving more weakly impressed 'transglabellar' branch, isolating small, depressed, median triangular area. Second pair shorter, deeply and backwardly directed near axial furrows but weakening into very gently curved depression adaxially, situated just in front of glabellar mid-length. Possible third pair seen as faint nick on glabellar surface just in from axial furrow, about half-way from 2P furrow to frontal glabellar margin. Occipital ring slightly wider (tr.) than rest of glabella, narrowing abaxially; trace of median node towards posterior margin may be base of small nuchial spine. Anterior border furrow broad and deep, separating very narrow rim-like anterior border from wider (sag. and exsag.), convex preglabellar field; the latter broadens into relatively narrow (tr.) preocular fixed cheek, about one-third width of glabella. Palpebral lobe of moderate size and narrow kidney-shaped outline. Postocular fixed cheek broader (tr.), triangular in outline; broad and deep posterior border furrow delimits convex, outwardly sloping border. Facial suture has almost parallel to slightly divergent preocular course, and outward and backwardly curving postocular path. Only vague impression of granulose ornamentation seen.

Remarks. This species is allied to the genus *Prosaukia* Ulrich and Resser, 1933 because, while it has a similar glabella character, preglabellar field, and anterior border, it also shows some differences, such as the presence of a pair of triangular lateral glabellar 1P lobes instead of the more typical development of a rectangular, transglabellar 1P lobe, and possibly it also has a nuchal node. Of the various described Australian species of *Prosaukia* and *Prosaukia*? it seems to bear closest resemblances to *P.* sp. A of Shergold (1975) from the upper Upper Cambrian Chatsworth Limestone of western Queensland in exhibiting traces of a lateral glabellar furrow 3P, and moderately sized palpebral lobes, and in lacking eye ridges. However, the Chatsworth species has a relatively wider (tr.) glabella, a more typical rectangular transglabellar 1P lobe and no trace of a nuchal node. Another species with similar features is *Saukia*? *aojii* Kobayashi 1933? (see Lu *et al.* 1965, p. 440, pl. 86, fig. 5) from the Fengshan Formation (upper Upper Cambrian) of Baijiashan, Wuhujui, Liaoning Province, China, but this differs in having a less well-differentiated anterior border furrow and a slightly wider glabella with less markedly V-shaped, inwardly and backwardly directed glabellar furrows 1P.

Family SAUKIIDAE Ulrich and Resser 1930?
Saukiid? gen. et sp. indet.

Text-fig. 4B

Material. One incomplete cranidium and thorax (SUP 49934) from the lower horizon (locality 1) in the upper part of the Watties Bore Formation, eastern side of Koonenberry Mountain, western New South Wales.

Description. Internal cast of small, imperfectly preserved cranidium, thorax of up to eleven segments and tiny, displaced, triangular pygidium. Cranidium with subquadrate glabella, rounding anteriorly; of almost equal glabellar width (tr.) and length (sag.). Two pairs of broad, shallow transglabellar furrows define weakly raised transversely elongate 1P and 2P lobes. Occipital ring narrow (sag.); right side partially underridden by first thoracic segment and consequently broken away. Preglabellar area very narrow (sag. and exsag.), in continuity with narrow (tr.) fixed cheek opposite palpebral lobe; widening posterolaterally into triangular postocular region. Deep posterior border furrow delimits narrow border.

Thorax with broad axis, tapering markedly backwards. Pleurae with deep, broad pleural furrows extending diagonally from anteromedian corner almost to posterolateral margin, dying out inside lateral extremities. Surface covered by fine granules.

Pygidium very small, transverse, with sharply tapering axis; three axial rings; pleural lobes smooth except for pleural furrow on first segment.

Remarks. This species is difficult to classify. It is referred tentatively to the saukiids because it has a low, subquadrate glabella with clearly differentiated transglabellar lobes 1P and 2P, a narrow preglabellar area, and preocular fixed cheek region, and a rapidly backwardly tapering thoracic axis. However, it has slightly wider (tr.) posterolateral limbs (that is, postocular regions of the fixed cheek) than are typically represented in this group, and this may suggest that, alternatively, a closer relationship with ptychaspidids (*Ptychaspis* Hall, 1863) or elviniids (*Chariocephalus* Hall, 1863). The presence of a tiny, transversely elongated subtriangular pygidium with few axial rings in a sharply backwardly narrowing axis is more typically seen in some elviniid genera.

Suborder ASAPHINA Salter, 1864
Superfamily CERATOPYGACEA Linnarsson, 1869
Family CERATOPYGIDAE Linnarsson, 1869
Subway IWAYASPIDINAE Kobayashi, 1962
Genus PSEUDOYUEPINGIA Chien, 1961

Type species. Pseudoyuepingia modesta Chien, 1961.

Emended diagnosis. Glabella parallel-sided to slightly forwardly tapering, with median glabellar tubercle placed in front of occipital ring at about twice its length (sag.); up to four pairs of poorly defined lateral glabellar furrows; more distinct backwardly arched occipital furrow but not continuous laterally into axial furrows; palpebral lobes of moderate size, may be near to or up to one-half glabellar width away from axial furrows; preglabellar field clearly differentiated from narrow anterior border; free cheek with lateral border prolonged into genal spine; thorax of eight or nine segments; pygidium varies from relatively smooth, less prominently segmented forms to those with up to eight axial rings, five pleural and interpleural furrows, and broad concave posterior border.

Discussion. This diagnosis is modified from that proposed by Jago (1987) to accommodate features such as the presence of a median glabellar tubercle, the palpebral lobes sometimes set well away from the glabella, the pleurae of the anterior thoracic segments not markedly spinose, and the pygidium varying between different species from relatively smooth to having well-segmented pleural areas.

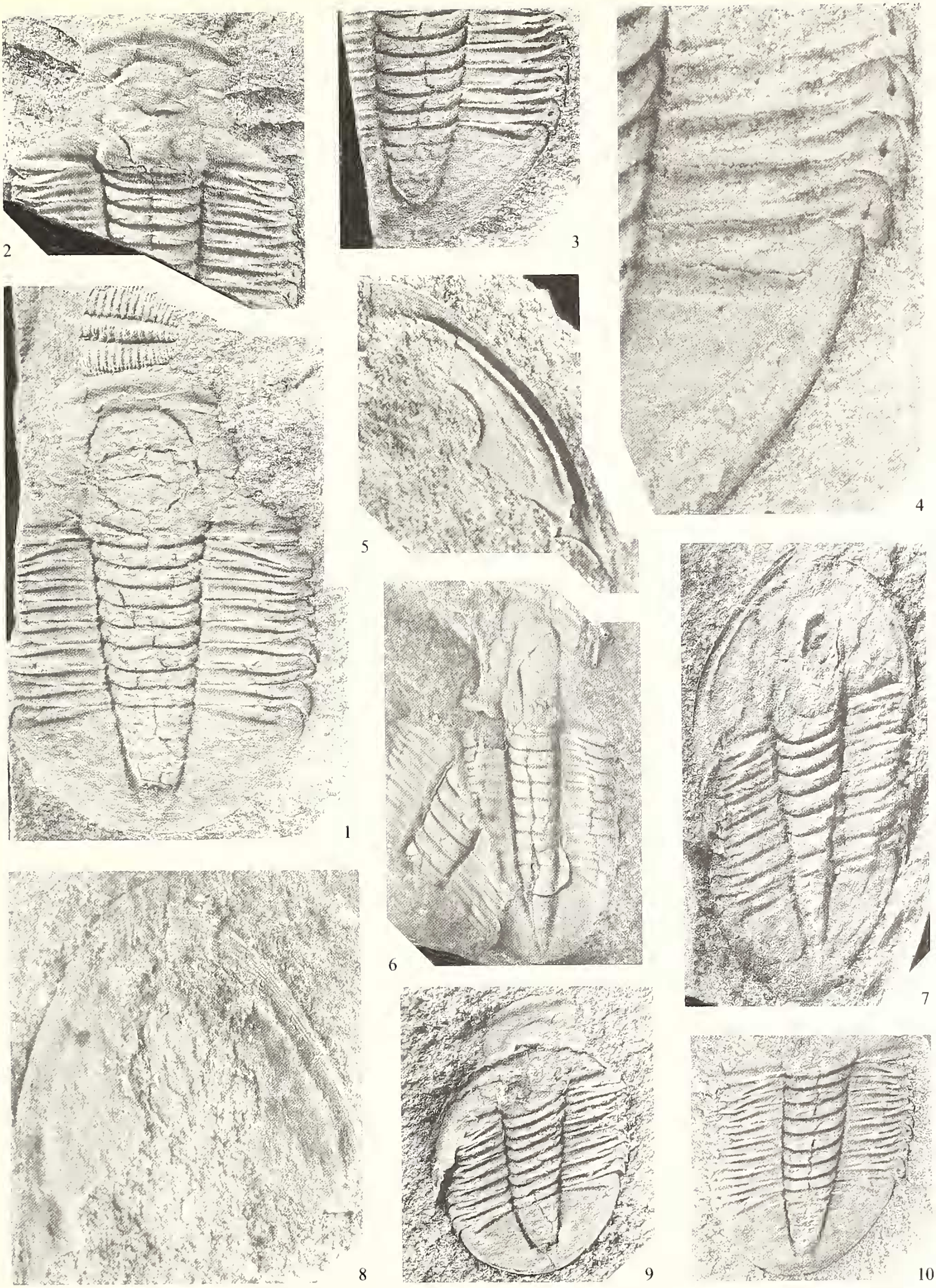
The genus *Pseudoyuepingia* Chien, 1961 has been assigned to the Ceratopygidae (Iwayaspidinae) by Kobayashi (1962) and Shergold (1980), and to the Asaphidae (Niobinae) by Lu *et al.* (1965), Qiu *et al.* (1983) and Xiang and Zhang (1985), in consequence of its morphologically intermediate position between the two groups. Closely related is the genus *Iwayaspis* Kobayashi, 1962, regarded by Shergold (1980) as having separate status from *Pseudoyuepingia*. However, the morphology of the type species of *Iwayaspis*, *I. asaphoides* Kobayashi, falls well within the range of variability of known species of *Pseudoyuepingia*, and is accommodated within the emended diagnosis given above. Indeed, apart from being markedly more slender, it is quite similar to the second New South Wales species of *Pseudoyuepingia* (*P. lata* sp. nov.) described herein. Following Qiu *et al.* (1983, p. 207), the genus *Iwayaspis* is therefore best viewed as a junior synonym of *Pseudoyuepingia*. But it seems preferable to adopt Shergold's classification of *Pseudoyuepingia* as a ceratopygacean of the subfamily Iwayaspidinae.

Pseudoyuepingia has a widespread distribution in Upper Cambrian successions of north-west, southern, and eastern China (from the Xinjiang Uighur Autonomous Region and from Guizhou, Hunan, Anhui, and Zhejiang Provinces), South Korea, and western New South Wales, Australia.

The only closely related Australian forms are *Cermatops* Shergold, 1980 from the post-Idamean

EXPLANATION OF PLATE 84

Figs. 1–10. *Pseudoyuepingia whitei* sp. nov., Watties Bore Formation, uppermost Cambrian. 1, internal mould of cranidium, thorax, and pygidium of holotype, SUP 48928, ×4. Note small specimen of *Pareuloma aculeatum* sp. nov., at top. 2, internal mould of cranidium and incomplete thorax of paratype, SUP 48931, ×4. 3, internal mould of incomplete thorax and pygidium of paratype, SUP 48936, ×4. 4, internal mould of enlarged part of thorax and pygidium, paratype, SUP 48940, ×8. 5, internal mould of free cheek, paratype, SUP 48944, ×5. 6, latex cast of external mould of partially complete dorsal exoskeleton, paratype, SUP 48935, ×3. 7, internal mould of near complete dorsal exoskeleton, paratype, SUP 48929, ×5. 8, latex cast of external mould of ventral side of cephalic doublure and hypostoma, paratype, SUP 48933, ×9. 9, latex cast of external mould of damaged, near complete dorsal exoskeleton of paratype, SUP 48941, ×3. 10, internal mould of fragmentary cranidium, complete thorax and pygidium, paratype, SUP 48932, ×3.



WEBBY, WANG and MILLS, *Pseudoyuepingia* part of the Late Cambrian Chatsworth Limestone of western Queensland and a possible species of *Yuepingia* Lu, 1956 from a similar level in the Georgina Limestone also in western Queensland (Henderson 1976). The genus *Cermatops* differs in having smaller palpebral lobes, less distinct eye ridges, and a pygidium with strongly developed postaxial ridge and very gently rounded anterolateral corners. *Yuepingia* Lu, 1956 is based on type species *Y. niobiformis* from the Upper Cambrian of southern China, and is distinguished by its relatively larger, more elongate, forwardly tapering glabella, weakly developed occipital furrow, narrow (tr.), poorly differentiated preglabellar area, and much larger palpebral lobes. *Psiloyuepingia* Qian and Qiu (*in* Qiu *et al.* 1983, p. 208) based on type species *P. cylindrica* from the Upper Cambrian of Anhui Province, eastern China, is another which may be compared but differs from *Pseudoyuepingia* in exhibiting a more elongate, parallel-sided glabella, larger palpebral lobes, and outwardly diverging preocular facial suture.

Pseudoyuepingia whitei sp. nov.

Plate 84, figs. 1–10

Material. Holotype (SUP 48928) and fifteen paratypes (SUP 48929, 48931–48944) from the lower horizon (locality 1) in the upper part of the Watties Bore Formation, eastern side of Koonenberry Mountain, western New South Wales.

Etymology. After Mr Alan White of Wonnaminta Station.

Diagnosis. Species of *Pseudoyuepingia* with a moderately short (sag.) preglabellar field of similar length (sag.) to the anterior border, moderately wide fixed cheeks with palpebral lobes about one-third glabellar width from the axial furrow and eye ridges, an incompletely differentiated occipital ring, eight thoracic segments, and a relatively smooth weakly segmented pygidium with up to four axial rings, and a pleural field with only one pair of pleural furrows.

Description. Exoskeleton elliptical in dorsal outline, usually a little less than 20 mm in length. Most of the material is flattened which does not greatly alter proportions but a few specimens have been tectonically distorted, thus altering proportions. Glabella with maximum width at level of occipital ring, tapering gently forwards and rounded anteriorly. Four pairs of rather ill-defined lateral glabellar furrows; 1P somewhat crescentic with concave side facing outwards, seemingly dividing glabella into three roughly equal parts—a median, and a pair of lateral glabellar lobes; 2P, 3P, and 4P are much fainter, inwardly and backwardly directed impressions near the axial furrows; 2P is opposite mid-length of palpebral lobe; 3P seemingly near opposite eye ridge, and 4P close to anterolateral corner of glabella. Occipital ring not well differentiated because of the discontinuous, weakly developed occipital furrow. Faint median glabellar tubercle developed in front of occipital furrow. Preglabellar area more or less equally divided (sag.) by conspicuous, broad anterior border furrow into anterior border and preglabellar field.

Palpebral lobes of moderate size, and situated at mid-length of cranidium, about one-third glabellar width from axial furrows. Eye ridge distinct, running from axial furrow towards rather poorly defined palpebral rim. Large L-shaped postocular area with a deep and broad posterior border furrow separating a narrow (exsag.) convex posterior border. Preocular facial suture runs in parallel-sided to very gently, outwardly curving arc to intersection with anterior border, then converges sharply inwards along rim of border. Postocular facial suture arcuate, diverging most sharply behind palpebral lobe.

Free cheek with relatively short genal spine, extending backwards to second or third thoracic segment. Deep posterior border furrow dies out approaching base of genal spine; anterior and lateral border furrow deep and relatively broad, also dying out posterolaterally. Narrow, raised lateral border broadens (tr.) into genal spine, this latter developing an associated longitudinal groove. Doublure broad beneath anterior border but narrows into lateral border; with up to fifteen terrace lines running subparallel to margin.

Only one very poorly preserved and deformed hypostoma has been found; it is weakly convex, generally ovate in outline and with very vague differentiation into larger rounded anterior and smaller transversely elliptical posterior lobes. Anterior wing with subtriangular form narrowing anteriorly. Lateral border extends from about mid-length of median body into broad posterior border with sharply V-shaped notched posterior margin.

Thorax of eight segments, with axis occupying between one-quarter and one-third total width. Axial rings of uniform width (sag.) and defined by deep axial and articulating furrows, with small apodemal pits at their junctions. Pleurae more or less transversely aligned but with anterior segments more strongly faceted and outwardly bluntly pointed; posteriorly, pleural segments more expanded, blade-like, and backwardly deflected into pointed tips, with conspicuous, circular Panderian openings on middle part of doublure. Pleural furrows broad, deep, and transverse but beyond fulcrum they narrow and become more diagonally directed, dying out near inner edge of doublure.

Pygidial axis subdivided by ring furrows into three, possibly four, axial rings and a semicircular-shaped terminal piece. Some specimens also show weakly developed, triangular-shaped postaxial ridge extending beyond terminal piece almost to posterior margin. Pleural field flattened and relatively smooth, with only the first pair of pleural furrows developed. Posterior and lateral borders not clearly differentiated from rest of smooth, flattened pleural field. Doublure extends in to tip of terminal piece and then runs in gentle curve towards anterolateral corner of pygidium; with about twelve terrace lines subparallel to margin.

Remarks. *P. whitei* sp. nov. is similar to *P. zhejiangensis* Lu and Lin, 1980 from the Upper Cambrian Xiyangshan Formation of Changshan and Jiangshan in Zhejiang Province of eastern China, in having only eight rather than nine thoracic segments, and a wider (tr.) area of fixed cheek at the level of the palpebral lobes, at least one-third of glabellar width. However, the Chinese species differs in exhibiting a more parallel-sided glabella, larger palpebral lobes, a relatively slightly narrower thoracic and pygidial axis, and more clearly defined segmentation of the pygidium. *P. distincta* Xiang and Zhang, 1985 from the uppermost zone in the Guozigou Formation (upper Upper Cambrian) of the western part of northern Tianshan, Xinjiang, north-west China, is also similar but exhibits a more parallel-sided glabella, markedly diverging preocular facial sutures, and a narrower anterior border with, immediately in front of the glabella, no clearly differentiated intervening preglabellar field. *P. whitei* may also be compared with type species *P. modesta* Chien, 1961 (see Lu *et al.* 1965) from the Upper Cambrian Sandu Formation of Sandu, Guizhou Province, southern China, in showing a gently forwardly tapering glabella, weakly developed lateral glabellar furrows (up to three or four pairs), a median glabellar tubercle towards the rear of the glabella, median-sized palpebral lobes with weak eye ridges crossing an area of fixed cheek which is at least one-third of glabellar width (tr.), an anterior border and preglabellar field of subequal width (sag.), and a comparatively similar pygidium. In contrast the glabella, the thoracic axis and pygidial axis of *P. whitei* are comparatively broader (tr.), the posterior border of the cranidium is narrower (exsag.), the posterior margin of the hypostoma is more distinctly notched, the thorax exhibits only eight segments with pleural extremities more backwardly deflected (hook-like), and Panderian openings are more conspicuous on the doublure.

The Idamean (late Cambrian) species of *Pseudoyuepingia*, *P. vanensis* Jago 1987, from the Singing Creek Formation of the Denison Range, south-west Tasmania, exhibits a similarly short (sag.) preglabellar field, but differs in having a more effaced and narrower (tr.) glabella and palpebral lobes set closer to the glabella, and it apparently lacks eye ridges, and has nine thoracic segments.

Pseudoyuepingia lata sp. nov.

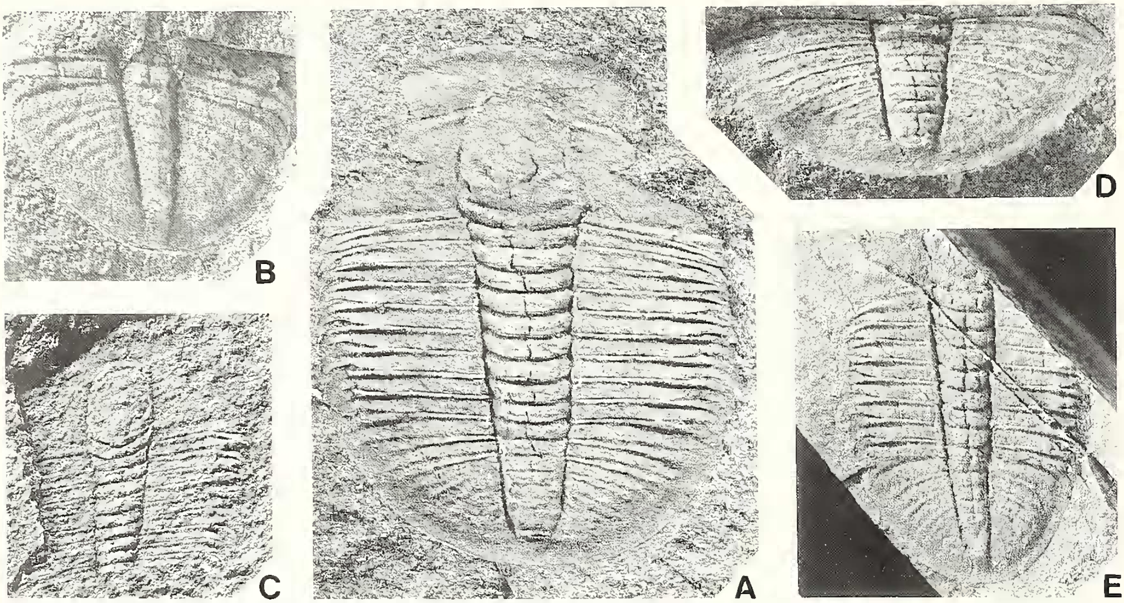
Text-fig. 5A–E

Material. Holotype (SUP 48947) and six paratypes (SUP 48945, 48948–48949, 49900–49902) from the lower horizon (locality 1) in the upper part of the Watties Bore Formation, eastern side of Koonenberry Mountain, western New South Wales.

Etymology. Latin, *latus*, broad, alluding to the wider (tr.) and longer (sag.) preglabellar field.

Diagnosis. Species of *Pseudoyuepingia* with a long (sag.) and wide (tr.) preglabellar field, long (tr.) and conspicuous eye ridges, and palpebral lobes with associated wide fixed cheeks (more than one-half glabellar width), a well-differentiated occipital ring, a thorax of nine segments with a relatively narrow (tr.) axis, and a pygidium with markedly more segmented axis (up to eight axial rings) and pleural lobes (up to five pleural and interpleural furrows).

Comparative description. The exoskeleton has a flattened, elliptical dorsal outline with a length/width ratio varying dependent on the degree of transverse or longitudinal extension (or compression), from 0·6 to 0·8 (as compared with *P. whitei* which has a length/width ratio of from 0·5 to 0·7). The proportions between cephalon and thorax are also slightly different because the thorax with its nine segments tends to be relatively slightly longer (sag.) than the cephalon. Glabella is slightly less markedly tapering forwards, with only apparently three pairs of rather ill-defined lateral glabellar furrows. 1P is developed as inward and backwardly directed impression, 2P and 3P as much shorter and less well-formed structures, the 3P furrows being situated adjacent to the eye ridges. A glabellar tubercle is present on the mid-line between the 1P furrows. The occipital ring is well defined by occipital furrow, though it is not completely continuous into the axial furrows. The preglabellar furrow bounds the frontal part of the glabella and is less deeply impressed than the axial furrows. A pair of small, pit-like fossulae lie on the axial furrows at anterolateral corners of the glabella. The gently convex preglabellar field is about twice as wide (sag.) as the raised, rim-like anterior border, and is more extended laterally (tr.). The width (tr.) across the fixed cheek at the mid-level (exsag.) of the palpebral lobe is more than half the glabellar width. The palpebral lobes are of moderate size, with a slightly raised, well-formed, crescentic palpebral rim which extends into the conspicuous eye ridge.



TEXT-FIG. 5. A–E, *Pseudoyuepingia lata* sp. nov., Watties Bore Formation, uppermost Cambrian. A, latex cast of external mould of cranidium, thorax, and pygidium of holotype, SUP 48947, ×4; B, internal mould of incomplete thorax and pygidium of paratype, SUP 48949, ×5; C, latex cast of external mould of incomplete cranidium and thorax of meraspid stage, paratype, SUP 49901, ×6; D, latex cast of external mould of pygidium of paratype, SUP 49900, ×3; E, internal mould of incomplete cranidium, thorax, and pygidium of paratype, SUP 48948, ×3.

The thorax is of nine segments. The axis occupies from between one-fifth and one-quarter of the width of the thorax. Pleural lobes are flattened and exhibit transversely aligned pleurae with backwardly deflected pointed pleural ends. The pleural furrows are broad and shallow, becoming deeper and directed more diagonally behind the fulcrum. Panderian openings may be seen on the doublure.

The pygidium has a moderately convex, narrow (tr.) axis, with up to seven axial rings, and a small semicircular terminal piece. The pleural fields exhibit up to five pairs of pleural and interpleural furrows, and a broad, smooth, slightly concave posterior border, only interrupted by the extension behind the axis of a weakly raised postaxial ridge.

Remarks. The differences between these two species of *Pseudoyuepingia* are quite considerable yet they occupy the same horizon at the particular collecting locality. This suggests they may be sexual dimorphs of the one species. Whittington (1965) has similarly noted this possibility in two species of the genus *Niobe* Angelin, 1851 (members of the subfamily Niobinae Jaanusson, 1959) from the Middle Ordovician of Newfoundland.

Of the more closely comparable East Asian species of *Pseudoyuepingia*, *P. zhejiangensis* Lu and Lin, 1980 has a more parallel-sided glabella, a shorter (sag.) and narrower (tr.) preglabellar field, and only eight thoracic segments, the type species, *P. modesta* Chien, 1961, has a relatively narrower glabella, narrower area of fixed cheek between palpebral lobes with shorter (tr.) less conspicuous eye ridges, less extended (sag.) preglabellar field, and less markedly segmented pygidium, and *P. asaphoides* (Kobayashi 1962) from the lower Upper Cambrian succession of the southern slopes of Mount Sambang-san, east of Seto, Puk-myon, South Korea, is overall a more slender (tr.) form with a narrower, more parallel-sided glabella and very faint, short (tr.) eye ridges on a narrow area of fixed cheek. An Alaskan species (thorax and pygidia only) from the Franconian 1 level of the Upper Cambrian, identified by Palmer (1968) as *P.* cf. *asaphoides* (Kobayashi 1962), shows a similar thorax of nine segments and pygidium but without associated cranidia cannot be closely identified with *P. lata*.

Other Chinese species like *P. aspinosa* Qian, 1983 (*in* Qiu *et al.* 1983) from the Qingkeng Formation (middle Upper Cambrian) of Qingkeng, Qingyang, Anhui Province, *P. laochatianensis* Yang (MS) (*in* Zhou *et al.* 1977; Yang 1978) from the lower Upper Cambrian of western Hunan Province, and *P. l. kontianwuensis* Qiu, 1983 (*in* Qiu *et al.* 1983) from the Tuanshan Formation (lower Upper Cambrian) of Huamiao, Guichi, also from Anhui Province, are characteristically small, slender forms, each with an elongated, parallel-sided glabella, and a prominent, gently raised median preglabellar ridge extending longitudinally from frontal margin of the glabella to the anterior border.

Subfamily PROCERATOPYGINAE Wallerius, 1895
Genus PROCERATOPYGE Wallerius, 1895

Type species. Proceratopyge conifrons Wallerius, 1895.

Discussion. Proceratopyge has a widespread distribution in the Middle–Upper Cambrian of Europe and the Upper Cambrian of the USSR, China, Alaska, Australia, and Antarctica (Shergold 1982). In China (Lu and Lin 1980) and Kazakhstan (Apollonov *et al.* 1984) *Proceratopyge* is recorded from the upper part of the Upper Cambrian. Rushton (1983) listed some forty-three named species of the genus, and an additional six species have recently been added to this list by Xiang and Zhang (1985) from the Upper Cambrian successions of the northern Tianshan, Xinjiang, northwestern China. Of the Australian Upper Cambrian species described previously by Whitehouse (1939), Öpik (1963), Henderson (1976), Shergold (1982), and Jago (1987), there are two species *P. nectans* Whitehouse and *P. cryptica* Henderson from the early Idamean and one species, *P. lata* Whitehouse from the late Idamean of western Queensland and *P. gordonensis* Jago from the Idamean of Tasmania. These occurrences are from substantially older Upper Cambrian deposits than the New South Wales record of *P. ocella* sp. nov. described herein.

Jago (1987) has recently recommended that the species of the genus *Proceratopyge* should be split into two broad groups based on various cranidial features. The New South Wales species belongs to the first group, comprising species with small palpebral lobes placed well forwards, large posterolateral limbs and preocular sections of the facial suture which diverge only slightly. In contrast all the described Idamean species from Queensland and Tasmania belong to Jago's second grouping, that is, they are forms with larger, more centroposteriorly placed, crescent-like palpebral lobes, 'strap-like' posterolateral limbs, and a sharply diverging preocular facial suture.

Proceratopyge ocella sp. nov.

Plate 85, figs. 1–10

Material. Holotype (SUP 49922) and eleven paratypes (SUP 49921, 49923–49931, 49937) from the lower horizon (locality 1) in the upper part of the Watties Bore Formation, eastern side of Koonenberry Mountain, western New South Wales.

Etymology. Latin, *ocellus*, a little eye, referring to the relatively small palpebral lobes.

Diagnosis. Species of *Proceratopyge* (first group of Jago 1987) with faint but clearly defined lateral glabellar furrows in front of 1P, a flattened anterior border, relatively small palpebral lobes placed just in front of glabellar mid-length, diverging preocular facial suture, up to 20° away from the exsagittal line, a relatively wide thoracic axis, and a pygidium with up to nine clearly defined axial and pleural segments, a wide, flattened posterolateral border and a moderately gently rounded anterolateral angle.

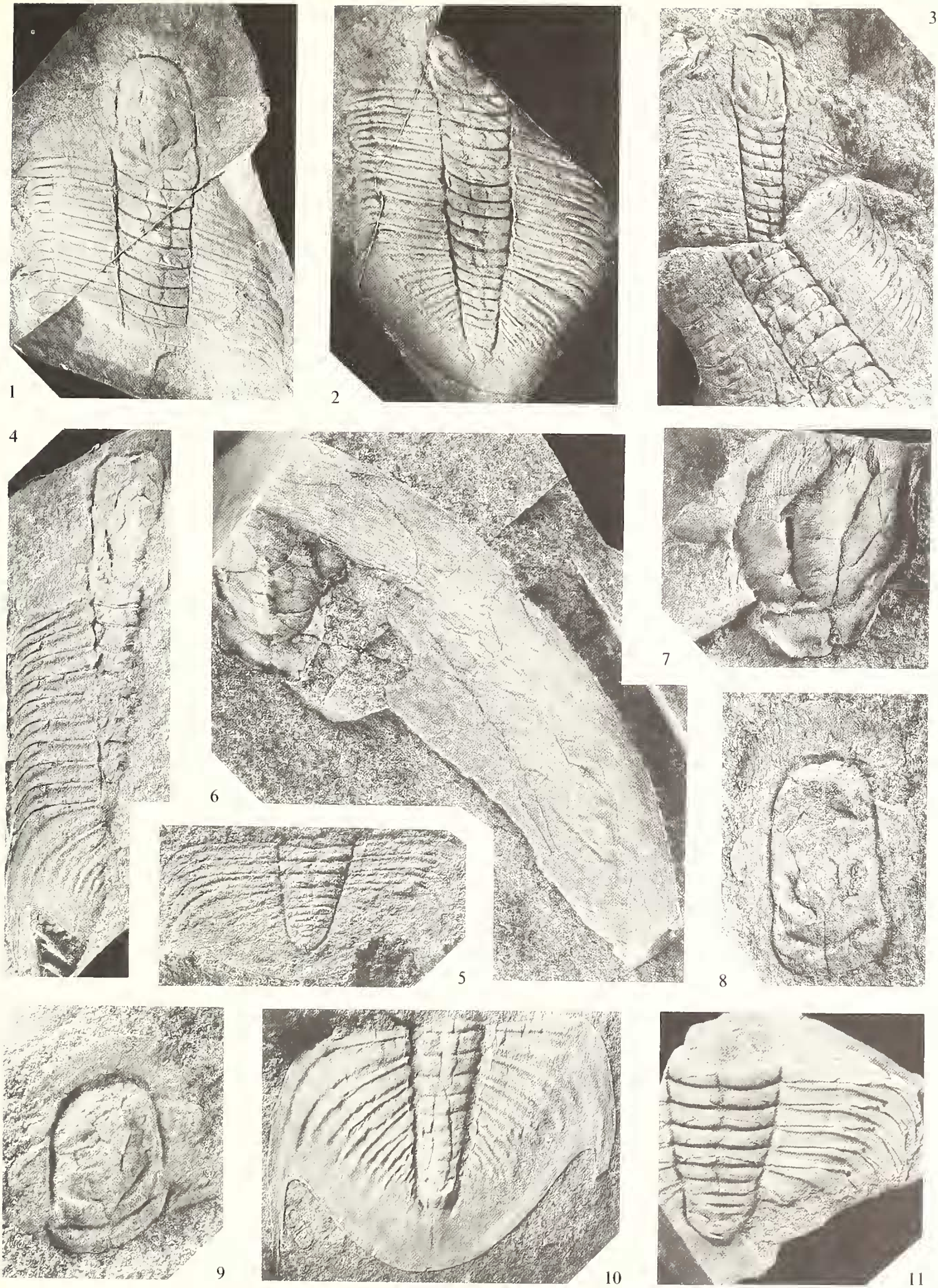
Description. Moderately large, flattened to gently convex, exoskeleton with a length (sag.) of up to 80 mm. Much of the material of this species is flattened but this does not markedly alter proportions. Glabella, apart from slight narrowing opposite 1P furrows, tapers gently forwards to its rounded anterior margin. Four pairs of lateral glabellar furrows; 1P developed as deeper, backwardly and inwardly curved depressions set well in from axial furrow, and just behind glabellar mid-length (sag.); 2P much more faintly impressed backward and inwardly directed impressions just in front of glabellar mid-length; 3P a faint, inward and forwardly directed slit-like depression, also well inside axial furrow; 4P only a little further forward and close to axial furrow, almost opposite eye ridge. Small median tubercle faintly developed near mid-length of 1P. Occipital furrow shallows medially but deepening laterally; deepest on exsagittal line of lateral glabellar furrows 1P–3P; not extending into axial furrows. Anterior border and preglabellar field subequal in width (sag. and exsag.); flattened and only weakly differentiated by broad, very shallow anterior border furrow. Eye ridge short, extending into well-defined, crescentic rim of palpebral lobes, placed just in front of glabellar mid-length (sag.) and between one-half and one-third glabellar width from axial furrows. Postocular cheeks triangular, with very shallow posterior border furrow weakly delimiting narrow posterior border. Preocular facial suture diverges at about 15–20° to sagittal line, then inward on to anterior margin. Postocular facial suture diverges sharply behind palpebral lobes, then in gentle sigmoidal course to posterior margin.

Broad cephalic doublure with its numerous concentrically aligned terrace lines and hypostoma shown in one specimen (Pl. 85, fig. 6); median suture not apparently developed as free cheeks are conjoined; preocular facial suture seems to be impressed on ventral doublure. Rostral plate unknown. Hypostoma has tongue-shaped outline; widest near mid-length (sag.). Ovate moderate convex median body divided by median furrow into large, rounded anterior and smaller, transversely elongated, crescentic, posterior lobe. A pair of prominent raised maculae on median furrow in continuity with lateral border furrow. Anterior wings large, triangular, directed outwards; no anterior border; narrow lateral border commences opposite hypostomal mid-length (sag.) and appears to extend backwards into crescentic posterior lobe; sharp angle between lateral and posterolateral margin; posterolateral border furrow separates very narrow, raised border from posterior lobe;

EXPLANATION OF PLATE 85

Figs. 1–10. *Proceratopyge ocella* sp. nov., Watties Bore Formation, uppermost Cambrian. 1, latex cast of external mould of cranidium and thorax of holotype, SUP 49922, ×1·5. 2, latex cast of external mould of incomplete cranidium, thorax, and pygidium of paratype, SUP 49923, ×1. 3, latex cast of external mould of cranidium and thorax of paratype, SUP 49926 (designated specimen at top), ×2·5. 4, latex cast of external mould of incomplete dorsal exoskeleton of paratype, SUP 49925, ×2. 5, internal mould of incomplete thorax and pygidium of meraspid stage, paratype, SUP 49931, ×6. 6, internal mould of cephalic doublure and hypostoma of paratype, SUP 49937, ×4. 7, internal mould of hypostoma of paratype, SUP 49930, ×3. 8, internal mould of incomplete cranidium of paratype, SUP 49921, ×3. 9, internal mould of cranidium of paratype, SUP 49924, ×3. 10, latex cast of external mould of pygidium of paratype, SUP 49927, ×1·5.

Fig. 11. *Proceratopyge* sp., Watties Bore Formation, uppermost Cambrian; internal mould of incomplete thorax and pygidium of specimen, SUP 49932, ×2.



WEBBY, WANG and MILLS, *Proceratopyge*

another sharp angle between posterolateral and posterior margin; also a weakly developed median notch. Anterior lobe has an ornamentation of concentrically arranged anastomosing terrace lines; other parts of hypostoma show terrace lines running parallel to margins.

Thorax of nine segments with almost parallel-sided axis. Pleural lobes flattened; individual pleurae transversely aligned, then curved backwards towards bluntly pointed tips; pleural furrows run in a slightly sigmoidal course, deepening towards the fulcrum, then weakening to die out inside pleural tips; terrace lines run subparallel to backwardly curving outer ends. Small rounded Panderian structures occur on doublure of outer part of pleurae. Inner margin of doublure has scalloped appearance, with associated terrace lines aligned subparallel to lateral margins.

Pygidium with axis slightly tapering backwards, and consisting of up to nine rings and semicircular terminal piece just inside posterior border. Up to nine pairs of pleural segments, the first prolonged into a long backwardly directed pleural spine. First pleural furrow curves in arc on to pleural spine, and second also extends on to flattened posterolateral border; the remaining pleural, and the interpleural, furrows do not extend on to border. Weakly developed postaxial ridge may also extend on to border. Doublure broad, widening anterolaterally away from postaxial ridge; terrace lines more or less subparallel to sigmoidally aligned inside posterolateral margins, and form in an acutely V-shaped pattern along large pleural spines.

Remarks. P. ocella sp. nov. belongs most closely to *Proceratopyge* (*Lopnorites*), based on the type species *P.* (*L.*) *rectispinata* Troedsson, 1937 from eastern Tianshan, Xinjiang, north-western China, in having eye ridges, a subparallel-sided glabella and six or more pygidial axial rings. Henderson (1976) pointed out the difficulties of recognizing such morphological features as consistently characterizing this particular subgenus, and recommended against its adoption as a valid subgenus. The species *P. rectispinata*, as described by Lu *et al.* (1965) and Palmer (1968) from China and Alaska, is similar to *P. ocella* except in having its palpebral lobes placed a little further forward on the cheek region, less clearly defined lateral glabellar furrows in front of 1P, a relatively narrower thoracic axis, and a less segmented pygidium with narrower border. *P. copiosa* Xiang and Zhang, 1985, also from the Tianshan region of Xinjiang, similarly resembles *P. ocella* but for the preocular facial sutures which are parallel (not diverging), the anterior border more conspicuously upraised and the pygidium with narrower posterior border, and more sharply rounded anterolateral angle. *P. constricta* Lu, 1964, recently assigned to another subgenus, *Sinoproceratopyge* Lu and Lin, 1980, from the upper part of the Upper Cambrian in the Wujiajian section of Jiangshan County in western Zhejiang Province, is a third Chinese species with resemblances to *P. ocella* but it has a more regularly parallel-sided, almost quadrate-shaped glabella, larger crescent-shaped palpebral lobes, and a subtriangular shaped pygidium.

One additional specimen (SUP 49932) of *Proceratopyge* from the same locality and horizon in the Watties Bore Formation may represent a second species. However, it is only represented by an incomplete thorax and pygidium (Pl. 84, fig. 11). In contrast to *P. ocella*, the pygidium is relatively shorter (sag.) and the axis only exhibits four axial rings and a terminal piece.

Genus HEDINASPIS Troedsson, 1951

Type species. Hedinia regalis Troedsson, 1937.

Discussion. This genus has a widespread occurrence in the Upper Cambrian of Asia, especially China (Zhejiang and Guizhou Provinces and Xinjiang Uighur Autonomous Region), Kazakhstan (Ergaliev 1983*a*), Alaska and the western United States, western New South Wales, Tasmania, and New Zealand. It is characteristic of Taylor's (1976) basinal biofacies, spanning the mid-Franconian to mid-Trempealeanan interval of central Nevada. The genus is known from horizons in the topmost part of the Upper Cambrian of western Zhejiang Province (Lu and Lin 1980) and Xinjiang Uighur Autonomous Region (Xiang and Zhang 1985) of China, and from New Zealand (Wright and Cooper 1983). It has also been found in a 'possible correlate' of the Climie Formation of late Late Cambrian age in Tasmania (Jago, *in* Shergold *et al.* 1985). In a direct line of descent from *Hedinaspis* is the genus *Neohedinaspis* Xiang and Zhang, 1984 (type species, *N. xinjiangensis* Xiang and Zhang, 1984) from the Tremadoc Sayram Formation of northern Tienshan, Xinjiang.

It differs in having a shorter and broader glabella, shorter eye ridges, short marginal pygidial spines, and lacks a preglabellar field.

Hedinaspis sp.

Text-fig. 4C

Material. One incomplete thorax (SUP 49938) from the lower horizon (locality 1) in the upper part of the Watties Bore Formation, eastern side of Koonenberry Mountain, western New South Wales.

Description. Ten segments of moderately sized, flattened thorax (probably posterior portion), showing backward tapering narrow (tr.) axis between one-fifth and one-sixth of total thoracic width; maximum width of specimen is 32 mm. Axial furrow moderately deep and scalloped around outwardly convex axial rings, with very gently backwardly arched, broad articulating furrows intersecting axial furrows at junctions between scallops. Axial rings of almost similar width (sag. and exsag.) posteriorly.

Remarks. This genus has a distinctive thorax allowing this flattened, partially complete specimen to be referred to it. However, it must be left in open nomenclature until less fragmentary material is found.

Two additional specimens from the same locality and horizon may also be allied to *Hedinaspis*, possibly to this same species. The first (SUP 49935) consists of an internal mould of an immature (early meraspis) stage (text-fig. 4D). Maximum width of the parallel-sided glabella is 0·6 of sagittal length. Faint impressions of three pairs of lateral glabellar furrows are developed just in from axial furrows. Occipital ring narrows (exsag.) laterally. Preglabellar field is relatively broad (sag.) and differentiated from narrow (sag.), raised anterior border. Fixed cheek is broad, with small to moderate sized, palpebral lobe, and narrow (exsag.) ridge-like posterior border. Free cheek is relatively narrow (tr.) with prolongation into slender genal spine. Thorax has a relatively narrow (tr.), gently convex axis and flattened pleural lobes, the pleurae with furrows and spine-like extremities. Indeed, the specimen has the typical features of the meraspis stage of *Hedinaspis* described by Taylor (1976), and is consequently attributed to it.

The second specimen (SUP 49933) is less confidently assigned to *Hedinaspis*. This single, incomplete, somewhat damaged cephalon and partial thorax (text-fig. 4E) has a maximum width of about 6 mm, and consequently probably also represents an immature (?late meraspid) stage. Glabella is almost parallel-sided with three pairs of rounded to transverse slot-like lateral glabellar furrows impressed on its outer slopes. Faint, tiny median node is seen in external mould between 1P and 2P furrows. Occipital ring has a markedly crescentic outline, possibly with a small median node. Preglabellar field is only slightly less than 0·2 of the total glabellar length (sag.) and not clearly showing anterior border. Fixed cheeks form gently convex subtriangular areas with poorly developed palpebral lobes. Free cheeks damaged by crushing but clearly with attenuation into genal spine. Thorax of at least four segments, with relatively broad axis and flattened pleural regions. Pleurae exhibit deep transverse pleural furrows, narrowing and posteriorly placed beyond the fulcrum, narrow articulating facets on anterolateral edges and slightly backwardly directed, and rather spine-like pleural tips. In summary the specimen shows a number of features, such as more prominent anterolateral facets on pleurae, an axis more than one-quarter of the total thoracic width, poorly formed palpebral lobes, and lack of eye ridges, which do not seem to be typical of the genus. Consequently, it is only doubtfully assigned to *Hedinaspis*.

Subfamily CERATOPYGINAE Linnarsson, 1869
Genus HYSTEROLENUS Moberg, 1898

Type species. Hysterolenus toernquisti Moberg, 1898.

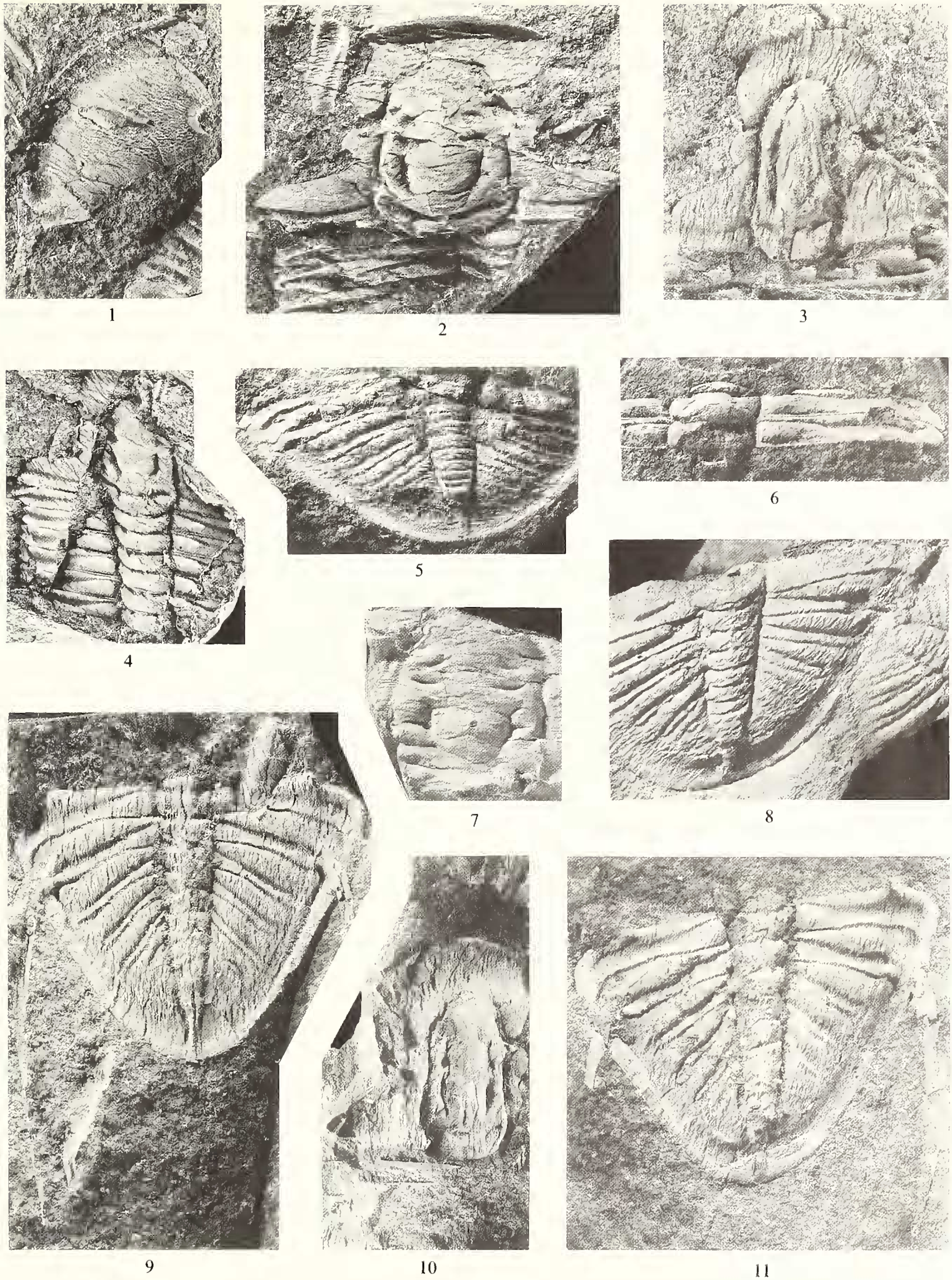
Discussion. The ceratopyginid genus *Hysterolenus* Moberg has until comparatively recently been viewed as having a restricted early Tremadoc age. In southern Sweden the *Hysterolenus* fauna with its type species *H. toernquisti*, is confined to the Dictyonema Shale (Bergström 1982). It comes from similar horizons in Kazakhstan (Nikitin *et al.* 1986), though Ergaliev (1983*a*) has also recorded the genus from what he regards as the higher part of the early Tremadoc, in strata of the Bol'shoy, Karatau, and Ulutau regions, and from the Altai-Sayan mountain region (Petrunina *et al.* 1984). *Hysterolenus* has been widely reported from early Tremadoc stratigraphic levels in northern and south-east China (Lai 1984). *H. tenuispinus* Lu and Zhou and *H. oblongus* Lisogor have been recorded from the Hangula region, W. Nei Monggol (Lu *et al.* 1981); *H. oblongus* from the Sayram Formation of the western part of northern Tianshan, Xinjiang Province (Xiang and Zhang 1984); and *H. asiaticus* Lu from the Yinchupu Formation of Changshan, western Zhejiang Province (Lu and Lin 1980). The range of this latter is the basis for the biostratigraphic subdivisions, the *Hysterolenus* Zone and the *Onychopyge–Hysterolenus* Assemblage Zone, used to correlate early Tremadoc successions in the Jiangnan 'shelf margin' region of south-east China (Lu *et al.* 1983, 1984; Peng 1983, 1984). Palaeogeographically the *Hysterolenus* occurrences are restricted to basin margin-type deposits to the north of the Tarim and North China Platforms, and to the south-east of the Yangzi Platform (Lai 1984).

Rushton (1982) has raised the possibility of *Hysterolenus* first appearing in the late Cambrian by finding an occurrence in the Bryn-llin-fawr section of North Wales, 22 m below the first record of *Dictyonema*. This appearance of *Dictyonema* is regarded by Rushton (1982) as indicating the base of the Tremadoc in Wales. However, the Welsh occurrence, while considered by Rushton (1982) to belong to the late Cambrian *Acerocare* Zone, is associated with forms traditionally characteristic of the Tremadoc such as *Niobella homfrayi homfrayi*, *Parabolina* (*Neoparabolina*) *frequens*, *Beltella nodifer*, and *Shumardia alata* (Rushton 1982). Alternatively, the Welsh species which is so far based on only one pygidium may like a *Hysterolenus*-type pygidium from the late Cambrian of China (Lu *et al.* 1965, pl. 116, fig. 7), represent a different genus. Owing to these lingering doubts relating to the identification and age of the Welsh material, it seems therefore that the genus *Hysterolenus* should continue to be regarded as one of the most useful, restricted early Tremadoc index fossils, apparently throughout its entire European, Asian, and Australasian geographic range.

The genus *Ruapyge* was erected by Wright (1979) with *R. hectori* (Reed 1926) as type species. Wright's descriptions were based on at least one of Reed's specimens, a pygidium (see Reed 1926, pl. 17, fig. 2c, and Kobayashi 1941, pl. 20, figs. 1–1′) designated as lectotype, and new collections made by him from the original type locality at Mount Patriarch, in the South Island of New Zealand. All the material, including Reed's type specimens, are poorly preserved and distorted, and consequently difficult to interpret. Wright (1979) noted the close morphological resemblances of *Ruapyge* to *Hysterolenus* but claimed that *Ruapyge* differed in having only three (instead of four) pairs of lateral glabellar furrows and up to eight (rather than from eight to ten) pygidial axial rings. The glabellar regions of Wright's illustrated specimens are badly distorted with much of the detail having been obliterated. Indeed, it is difficult to identify in any of his photographic illustrations of the material (Wright 1979, pls. 1 and 2), the same patterns of 2P and 3P furrows he has shown in his reconstruction of *R. hectori* (Wright 1979, fig. 2). He does not depict a 4P

EXPLANATION OF PLATE 86

Figs. 1–11. *Hysterolenus furcatus* sp. nov., Watties Bore Formation, basal Ordovician. 1, latex cast of external mould of free cheek of paratype SUP 49907, ×2. 2, latex cast of external mould of cranidium and incomplete thorax of holotype, SUP 49903, ×2. 3, latex cast of external mould of cranidium of paratype, SUP 49906, ×3. 4, latex cast of external mould of cranidium and incomplete thorax of paratype, SUP 49905, ×2. 5, internal mould of pygidium of paratype, SUP 49916, ×2·5. 6, internal mould of thoracic segments of paratype, SUP 49913, ×2. 7, internal mould of incomplete cranidium of paratype, SUP 49918, ×2·5. 8, internal mould of pygidium of paratype, SUP 49919 (designated specimen to left side), ×3. 9, latex cast of external mould of pygidium of paratype, SUP 49908, ×2. 10, internal mould of incomplete cranidium of paratype, SUP 49904, ×2. 11, internal mould of pygidium of paratype, SUP 49910, ×2.



WEBBY, WANG and MILLS, *Hysterolenus*

furrow yet there seems to be some evidence of one in his plate 2*b*, with a pair of small forwardly and inwardly directed slits running off the axial furrows in front of the eye ridges as in *Hysterolenus*. *R. hectori* has the same type of subtriangular pygidium with narrowly tapering axis, even traces of a postaxial ridge, and the long, slender, backwardly directed pleural spines from the second segment, as in *Hysterolenus*. The lesser number of axial rings may be an expression of the poor state of preservation, with especially some of the smaller rings in the posterior part of the pygidial axis being selectively destroyed in the deformation. Consequently, we regard *Ruapyge* as a subjective junior synonym of *Hysterolenus*.

Hysterolenus furcatus sp. nov.

Plate 86, figs. 1–11

Material. Holotype (SUP 49903) and seventeen paratypes (SUP 49904–49920) from the upper horizon (locality 2) in the uppermost part of the Watties Bore Formation, eastern side of Koonenberry Mountain, western New South Wales.

Etymology. Latin, *furcatus*, forked, alluding to the bifurcation of the lateral glabellar furrow 1P.

Diagnosis. Species of *Hysterolenus* with a relatively elongate, slightly forwardly tapering glabella, a conspicuous, deeply indented, long and forked lateral glabellar furrow 1P, a moderately extended preglabellar area, an almost continuous, well-defined occipital furrow, and an elongated, subtriangular-shaped pygidium with relatively slender axis of nine to eleven axial rings, pleural field of five to seven ribs, and long, slender marginal spines.

Description. Proportions of cranidium vary because of distortion from just less than twice as wide as long to slightly wider than long. Glabella tapers gently forwards from maximum width near base, though with slight outward bulge of 4L lobe; maximum width of glabella varies from 0·5 to 0·9 of sagittal length (including occipital ring); undistorted maximum glabellar width about 0·65 length; four pairs of lateral glabellar furrows; 1P, 2P, and 3P confined well away from axial furrows; 1P most conspicuous, deep, sigmoidally curved depression, directed mainly backwards and slightly inwards, and with short, laterally directed fork on outer side; 2P and 3P transversely aligned to rounded slots, 2P near the mid-length of glabella opposite palpebral lobes, and 3P slightly less conspicuously developed in front of palpebral lobes; 4P is a small slit-like furrow lying just in front of 3P, but close to axial furrow. Small median tubercle seen near mid-length of 1P in some external moulds. Occipital ring bounded by occipital furrow which deepens laterally into apodemal pits, but is not continuous into axial furrow; from apodemal pits a pair of branch furrows bifurcate backwards and inwards across occipital ring. Axial furrows at anterolateral corners of glabella exhibit deep, slit-like fossulae. Preglabellar field gently concave, extending to 0·25 of glabellar length (sag.) and widening abaxially; anterior border furrow separates brim-like, laterally tapering anterior border from rest of preglabellar area. Palpebral lobes small, crescentic, only slightly elevated and placed near mid-length of glabella, extending into short, weakly developed, eye ridges. Posterior border of uniform width (exsag.). Preocular facial suture diverges at between 25 to 35° to exsagittal line, then curves adaxially beneath rim of anterior border. Postocular suture diverges sharply behind palpebral lobes then more gently to posterior margin.

Free cheeks broad, gently convex, and with narrow, rim-like lateral border in continuity with long, slender genal spines. Lateral border furrow broad and shallow, dying out towards base of genal spine; posterior border and furrow not clearly differentiated. Genal caeca of fine radiating and forking lines running across cheek from near base of eye. Doublure broad, with up to ten terrace lines. Rostrum and hypostoma unknown.

Thorax with up to six segments; possibly maximum number for the species. Axis relatively narrow (tr.), occupying about one-fifth the width of thorax. Anterolateral slopes of axial ring notched by a pair of apodemal pits set adjacent to articulating furrow, well inside axial furrow. Pleura crossed by diagonally directed pleural furrow beginning as narrow groove close to anterior margin, widening abaxially, but then narrowing again to die out on prolongation into blunt pleural spine. Axial and pleural furrows, and a transverse, posteriorly placed furrow outline gently raised adaxial pleural lobe.

Pygidium large, with length/width ratio varying between 0·5 and 0·8 on available, mainly deformed, material. Axis narrow (tr.), about 0·15 of maximum pygidial width, and tapering gently backwards, with nine to eleven axial rings and a postaxial ridge extending across border on to posterior extremity. Pleural fields with seven pairs of pleural ribs, the last two being poorly developed. Pleural furrows, at least the first five, extend obliquely across pleural ribs as deep and wide grooves, narrowing adaxially and abaxially.

Interpleural furrows also well developed as narrower, sharp grooves, outlining clearly the first five pleural ribs; more posteriorly placed, more closely parallel to adjacent pleural furrows. Pair of long, slender, marginal spines issue from second pygidial segment and extends backward beyond the posterior margin of pygidium, to at least half its sagittal length; marginal spine has at least one longitudinal furrow and faint longitudinally orientated terrace lines. Smooth curvature of relatively narrow posterior border only interrupted by intersection of marginal spines and postaxial ridge. Doublure broad, evenly curved with up to fifteen terrace lines.

Remarks. Compared with other species of *Hysterolenus*, *H. furcatus* sp. nov. is apparently most closely related to the Baltoscandian type species, *H. toernquisti* Moberg, 1898 and to the Chinese *H. tenuispinus* Lu and Zhou, 1981 (*in* Lu *et al.* 1981). It differs from *H. toernquisti* in having a more elongate (exsag.) and more conspicuously forked lateral glabellar furrow 1P, more marked occipital furrow and longer, backwardly directed pleural spines. It may be distinguished from *H. tenuispinus* by exhibiting a relatively longer (sag. and exsag.) preglabellar area, a more conspicuous and adaxially more continuous occipital furrow, and a slightly more elongated (exsag.) backwardly directed arm of the forked 1P furrow.

Other species seem to be more markedly different. For instance, *H. asiaticus* Lu, 1959 (see Lu *et al.* 1965; Lu and Lin 1980, 1984) has a relatively broader (tr.), almost parallel-sided glabella and a relatively more transverse pygidium, with fewer axial rings in a broader (tr.) and shorter (sag.) terminally more abruptly tapering axis, and fewer pleural ribs. *H. oblongus* Lisogor, 1961 has a similar glabellar shape but the 1P furrows are set relatively further in towards the median node, and the pygidium appears to exhibit fewer axial rings. *H. sarysaiensis* Ergaliev, 1983*b*, also from the early Tremadoc of Kazakhstan, is only based on one incomplete pygidium, and similarly has fewer (seven or eight) pygidial axial rings. *H. hectori* (Reed 1926), from the early Tremadoc of New Zealand (Wright 1979), despite its highly deformed and poorly preserved nature, seems most closely to resemble *H. asiaticus* in having a broad, almost parallel-sided glabella, a relatively short preglabellar field, and a transversely extended pygidium with a broad, blunt, less segmented axis.

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REFERENCES

ANGELIN, N. P. 1851–1854. *Palaeontologica Scandinavica*. Pars. I *Crustacea formationis transitionis*, 1–24, pls. 1–24; Pars. II, pp. i–ix, 25–92, pls. 25–41. Academiae Regiae Scientarium Suecanae (Holmiae), Lund.

APOLLONOV, M. K., CHUGAEVA, M. N. and DUBININA, S. V. 1984. *Trilobites and conodonts from the Batyrbay section (uppermost Cambrian–Lower Ordovician) in Malyi Karatau Range*. Atlas of palaeontological plates, 1–48, pls. 1–32. Academy of Sciences of the Kazakh SSR, Order of the Red Banner of Labour, K. I. Satpaev Institute of Geological Sciences, 'Nauka' Kazakh SSR Publishing House, Alma-Ata. [In Russian.]

BARRANDE, J. 1868. Silurische Fauna aus der Umgebung von Hof in Bayern. *Neues Jb. Miner.* 641–696, pls. 6–7.

BERGSTRÖM, J. 1982. Scania. *In* BRUTON, D. L. and WILLIAMS, S. H. (eds.). Field excursion guide. IV Int. Symp. Ordovician System, *Paleont. Contr. Univ. Oslo*, **279,** 184–197.

BRONGNIART, A. 1822. Les Trilobites. *In* BRONGNIART, A. and DESMAREST, A. G. 1822. *Histoire naturelle des Crustacés fossiles sous les rapports zoologiques et géologiques*, 1–58, pls. 1–6. F. G. Levrault, Paris.

BRUNKER, R. L., OFFENBERG, A. and ROSE, G. 1971. Koonenberry, 1:500 000 Geological Series Sheet. Department of Mines, NSW.

CHIEN YI-YUAN. 1961. Cambrian trilobites from Sandu and Duyun, southern Kweichow. *Acta palaeont. sin.* **9** (2), 91–139, pls. 1–5. [In Chinese with English summary.]

ERGALIEV, G. K. 1983*a*. The Cambrian-Ordovician boundary in southern Kazakhstan and Ulutau. *In* APOLLONOV, M. K., BANDELETOV, S. M. and IVSHIN, N. K. (eds.). *The Lower Palaeozoic Stratigraphy and Palaeontology of Kazakhstan*, 6-16. Academy of Sciences of the Kazakh SSR, Order of the Red Banner of Labour, K. I. Satpaev Institute of Geological Sciences, 'Nauka' Kazakh SSR Publishing House, Alma-Ata. [In Russian.]

—— 1983*b*. Certain Upper Cambrian and Lower Ordovician trilobites of High Karatau and Ulutau. *In* APOLLONOV, M. K., BANDALETOV, S. M. and IVSHIN, N. K. (eds.). *The Lower Palaeozoic Stratigraphy and Palaeontology of Kazakhstan*, 35-66, pls. 1-6. Academy of Sciences of the Kazakh SSR, Order of the Red Banner of Labour, K. I. Satpaev Institute of Geological Sciences, 'Nauka' Kazakh SSR Publishing House, Alma-Ata. [In Russian.]

FORTEY, R. A. 1980. The Ordovician trilobites of Spitzbergen. III. Remaining trilobites of the Valhallfonna Formation. *Skr. norsk Polarinst.* **171,** 1-113, pls. 1-25.

—— 1983. Cambrian-Ordovician trilobites from the boundary beds in western Newfoundland and their phylogenetic significance. *In* BRIGGS, D. E. G. and LANE, P. D. (eds.). Trilobites and other early arthropods: papers in honour of Professor H. B. Whittington, F.R.S. *Spec. Pap. Palaeont.* **30,** 179-211, pls. 23-27.

—— LANDING, E. and SKEVINGTON, D. 1982. Cambrian-Ordovician boundary sections in the Cow Head Group, western Newfoundland. *In* BASSETT, M. G. and DEAN, W. T. (eds.). *The Cambrian-Ordovician boundary: sections, fossil distributions and correlations*, 95-129. National Museum of Wales, Geological Series, no. 3, Cardiff.

HALL, J. 1863. Preliminary notice of the fauna of the Potsdam Sandstone. *New York State Cabinet, Nat. History, Albany. 16th Ann. Rep., Appendix D*, 119-184.

HENDERSON, R. A. 1976. Idamean (early Upper Cambrian) trilobites from north-western Queensland, Australia. *Palaeontology*, **19,** 325-364, pls. 47-51.

HOWELL, B. F. 1935. Some New Brunswick Cambrian agnostians. *Bull. Wagner Inst. Sci. Philad.* **10,** 13-16, pl. 1.

JAANUSSON, V. 1959. Asaphidae. *In* MOORE, R. C. (ed.). *Treatise on invertebrate paleontology. Part O. Arthropoda 1*, 334-355. Geological Society of America and University of Kansas Press, Boulder, Colorado and Lawrence, Kansas.

JAEKEL, O. 1909. Ueber die Agnostiden. *Z. dt. geol. Ges.* **61,** 380-401.

JAGO, J. B. 1987. Idamean (Late Cambrian) trilobites from the Denison Range, south-west Tasmania. *Palaeontology*, **30,** 207-231.

JELL, P. A. 1975. Australian Middle Cambrian eodiscoids with a review of the superfamily. *Palaeontographica*, **A150,** 1-97, pls. 1-29.

—— 1985. Tremadoc trilobites of the Digger Island Formation, Waratah Bay, Victoria. *Mem. Mus. Vict.* **46,** 53-88, pls. 19-33.

JONES, P. J., SHERGOLD, J. H. and DRUCE, E. C. 1971. Late Cambrian and Early Ordovician stages in western Queensland. *J. geol. Soc. Aust.* **18,** 1-32.

KOBAYASHI, T. 1933. Upper Cambrian of the Wuhutsui Basin, Liaotung, with special reference to the limit of the Chaumitien (or Upper Cambrian) of eastern Asia, and its subdivision. *Jap. Jl Geol. Geogr.* **11** (1-2), 55-155, pls. 9-15.

—— 1935. The *Briscoia* fauna of the late Upper Cambrian in Alaska with descriptions of a few Upper Cambrian trilobites from Montana and Nevada. Ibid. **12** (3-4), 39-57, pls. 8-10.

—— 1939. On the agnostids (Part 1). *Jour. Fac. Sci. Univ. Tokyo, ser. 2*, **5,** 69-198.

—— 1941. On the occurrence of *Tailungshania*, a characteristic Arenigian trilobite, in New Zealand. *Jap. J. Geol. Geogr.* **17,** 195-201.

—— 1955. The Ordovician fossils from the McKay Group in British Columbia, western Canada, with a note on the Early Ordovician palaeogeography. *J. Fac. Sci. Tokyo Univ. sec. 2*, **9,** 355-493, pls. 1-9.

—— 1962. The Cambro-Ordovician formations and faunas of South Korea, part IX. Palaeontology VIII. The Machari fauna. Ibid. **14,** 1-152, pls. 1-12.

—— 1966. The Cambro-Ordovician formations and faunas of South Korea, Part 10. Stratigraphy of the Chosen Group in Korea and South Manchuria and its relation to the Cambro-Ordovician formations of other areas. Section A. The Chosen Group of South Korea. Ibid. **16,** 1-84.

LAI CAIGEN. 1984. The Tremadoc Series in China. *Aust. Jl Earth Sci.* **31,** 1-6.

LAKE, P. 1906. A monograph of the British Cambrian trilobites. *Palaeontogr. Soc.* [*Monogr.*], Pt. 1, 1-28, pls. 1-2.

LEITCH, E. C., WEBBY, B. D., MILLS, K. J. and KOLBE, P. 1987. Terranes of the Wonominta Block, far western

New South Wales. *In* LEITCH, E. C. and SCHEIBNER, E. (eds.). *Terrane accretion and orogenic belts*, 31–37. American Geophysical Union, Washington D.C.

LINNARSSON, J. G. O. 1869. Om Vestergotlands cambriska och siluriska, flagringar. *Handl. K. svenska Vetenskapsakad. Stockholm*, **8,** (2), 3–89.

LISOGOR, K. A. 1961. Tremadocian trilobites and their associates in the deposits of the Kendyktas. *Trans. Geol. Inst., Moscow*, **18,** 55–91, pls. 1–4. [In Russian.]

LU YANHAO. 1956. An Upper Cambrian trilobite faunule from eastern Kucichou. *Acta palaeont. sin.* **4** (3), 365–380, pl. 1. [In Chinese.]

—— 1959. Guide-book, Excursion to W. Zhejiang, 1–28, pls. 1–5. [In Chinese.] [Not seen.]

—— 1964. Trilobita (*partim*). *In* WANG YU (ed.). *Index fossils of South China*, 32–35, 42–47. Science Press, Beijing. [In Chinese.] [Not seen.]

—— and LIN HUANLING. 1980. Cambro-Ordovician boundary in western Zhejiang and the trilobites contained therein. *Acta palaeont. sin.* **19** (2), 118–135, pls. 1–3. [In Chinese with English summary.]

—— —— 1984. Late late Cambrian and earliest Ordovician trilobites of Jiangshan–Changshan area, Zhejiang. In *Stratigraphy and palaeontology of systemic boundaries in China. Cambrian–Ordovician boundary*, **1,** 45–143, pls. 1–19. Anhui Science and Technology Publishing House, Hefei.

—— CHANG WENTANG, CHU CHAOLING, CHIEN YIYUAN and HSIANG LIWEN. 1965. *Trilobites of China*, vol. 1, 1–362, pls. 1–66; vol. 2, 363–766, pls. 67–135. Science Press, Beijing. [In Chinese.]

—— CHU CHAOLING, CHIEN YIYUAN, LIN HUANLING, CHOW TSEYI and YUAN KEXING. 1974. Bio-environmental control hypothesis and its application to the Cambrian biostratigraphy and palaeozoology. *Mem. Nanjing Inst. Geol. Palaeont.* **5,** 27–116, pls. 1–4.

—— LIN HUANLING, HAN NAIREN, LI LUOZHAO and JU TIANYIN. 1983. Cambrian–Ordovician boundary of Jiangshan–Changshan area. In *Papers for the Symposium on the Cambrian–Ordovician and Ordovician–Silurian Boundaries, Nanjing, China, October 1983*, 1–5. Nanjing Institute of Geology and Palaeontology, Nanjing.

—— —— —— —— —— 1984. On the Cambrian–Ordovician boundary of the Jiangshan–Changshan area, W. Zhejiang. In *Stratigraphy and palaeontology of system boundaries in China. Cambrian–Ordovician boundary*, **1,** 9–44. Anhui Science and Technology Publishing House, Hefei.

—— ZHOU ZHIYI and ZHOU ZHIGIANG. 1981. Cambrian–Ordovician boundary and their related trilobites in the Hangula region, W. Nei Monggol. *Bull. Chin. Acad. Geol. Sci. ser. 10*, **2** (1), 1–19, pls. 1–3. [In Chinese with English summary.]

M'COY, F. 1849. On the classification of some British fossil Crustacea, with notices of new forms in the University collection at Cambridge. *Ann. Mag. nat. Hist. ser. 2*, **4,** 161–179, 392–414.

MATTHEW, G. F. 1887. Illustrations of the fauna of the St. John Group, No. IV, pt. I, Description of new species of *Paradoxides* (*Paradoxides regina*). Pt. II, The smaller trilobites with eyes (Ptychoparidae and Ellipsocephalidae). *Trans. Proc. R. Soc. Can.* **5,** 115–166, pls. 1–2.

MILLER, S. A. 1889. *North America geology and paleontology for the use of amateurs, students and scientists*, 718 pp., 1265 figs. Cincinnati, Ohio.

MOBERG, J. C. 1898. Om Acerocarezonen. *Geol. För. Stockh. Förh.* **20,** 197–290, pls. 10–14.

NALETOV, B. F. and SIDORENKO, T. F. 1970. Early Ordovician volcanic assemblages of Salair Ridge. *Geologiya Geofiz. Novosibirsk* **1970** (5), 72–78. [In Russian.]

NIKITIN, I. F., APOLLONOV, M. K., TZAI, D. T., KOROLJOV, V. G., KIM, A. I., ERINA, M. V., LARIN, N. M. and GOLIKOV, A. N. 1986. The Ordovician System in Kazakhstan and Middle Asia. Correlation charts and explanatory notes. *Int. Union Geol. Sci. Publ.* **21,** 1–34.

ÖPIK, A. A. 1963. Early Upper Cambrian fossils from Queensland, *Bull. Bur. Miner. Resour. Aust.* **64,** 1–133, pls. 1–9.

—— 1967*a*. The Ordian Stage of the Cambrian and its Australian Metadoxididae. Ibid. **92,** 133–169.

—— 1967*b*. The Mindyallan fauna of North-Western Queensland. Ibid. **74** (2 vols.), 1–404, 1–167, pls. 1–67.

—— 1970. *Redlichia* of the Ordian (Cambrian) of northern Australia and New South Wales. Ibid. **114,** 1–66, pls. 1–14.

—— 1975*a*. Templetonian and Ordian xystridurid trilobites of Australia. Ibid. **121,** 1–84, pls. 1–32.

—— 1975*b*. Cymbric Vale fauna of New South Wales and Early Cambrian biostratigraphy. Ibid. **159,** 1–78, pls. 1–7.

—— 1979. Middle Cambrian agnostids: systematics and biostratigraphy. Ibid. **172** (2 vols.), 1–188, pls. 1–67.

ÖPIK, A. A. 1982. Dolichometopid trilobites of Queensland, Northern Territory and New South Wales. Ibid. **175,** 1–85, pls. 1–32.

PALMER, A. R. 1955. Upper Cambrian Agnostidae of the Eureka District, Nevada. *J. Paleont.* **29,** 86–101, pls. 19–20.

—— 1968. Cambrian trilobites of east-central Alaska. *US Geol. Surv., Prof. Paper,* **559-B,** 1–115, pls. 1–13.

PENG SHANCHI. 1983. Cambrian–Ordovician boundary in the Cili–Taoyuan border area, northwestern Hunan. In *Papers for the Symposium on the Cambrian–Ordovician and Ordovician–Silurian boundaries, Nanjing, China 1983,* 44–52, pls. 1–3. Nanjing Institute of Geology and Palaeontology, Nanjing.

—— 1984. Cambrian-Ordovician boundary in the Cili–Taoyuan border area, northwestern Hunan with descriptions of the relative trilobites. In *Stratigraphy and Palaeontology of systemic boundaries in China. Cambrian–Ordovician boundary,* **1,** 285–405, pls. 1–18. Anhui Science and Technology Publishing House, Hefei.

PETRUNINA, Z. E., SENNIKOV, N. V., ERMIKOV, V. D., ZEIFERT, L. L., KRIVCHIKOV, A. V. and PUZYREV, A. A. 1984. Lower Ordovician Stratigraphy of the Gorny Altai. *Trudy Inst. Geol. Geofiz., sib. Otd. Akad. Nauk SSSR,* **565,** 3–33. [In Russian.]

POCOCK, K. J. 1974. *Estaingia,* a new trilobite genus from the Lower Cambrian of South Australia. *Palaeontology,* **7,** 458–471.

POGSON, D. J. and SCHEIBNER, E. 1971. Pre-Upper Cambrian sediments east of Copper Mine Range, New South Wales. *NSW geol. Surv. Quart. Notes,* **4,** 3–8.

POWELL, C. MCA., NEEF, G., CRANE, D., JELL, P. and PERCIVAL, I. G. 1982. Significance of Late Cambrian (Idamean) fossils in the Cupala Creek Formation, northwestern New South Wales. *Proc. Linn. Soc. NSW,* **106,** 127–150.

QIAN YIYUAN. 1985. Late late Cambrian trilobites from the Tangcun Formation of Jingxian, southern Anhui. *Palaeontologia Cathayana,* **2,** 137–167.

QIU HONGAN, LU YANHAO, ZHU ZHAOLING, BI DECHANG, LIN TIANRUI, ZHOU ZHIYI, ZHANG QUANZHONG and QIAN YIYUAN. 1983. Trilobita. In *Palaeontological Atlas of East China. Volume of Early Palaeozoic,* 28–254, pls. 11–88. Geological Publishing House, Beijing. [In Chinese.]

RASETTI, F. 1954. Early Ordovician trilobite faunules from Quebec and Newfoundland. *J. Paleont.* **28,** 581–587.

—— 1966. Revision of the North American species of the Cambrian trilobite genus *Pagetia.* Ibid. **40,** 502–511.

REED, F. R. C. 1926. New trilobites from the Ordovician beds of New Zealand. *Trans. R. Soc. NZ,* **57,** 310–314.

ROBISON, R. A. and PANTOJA-ALOR, J. 1968. Tremadocian trilobites from the Nochixtlán region, Oaxaca, Mexico. *J. Paleont.* **42,** 767–800, pls. 97–104.

ROSE, G. 1974. Explanatory notes on the White Cliffs 1:250 000 Geological Sheet. Geol. Surv. NSW, Sydney, 1–48.

—— LOUDEN, A. G. and O'CONNELL, P. 1964. White Cliffs Sheet SH 54-12, 1:250 000 Geological Series (1st edn.). Geol. Surv. NSW, Sydney.

RUSHTON, A. W. A. 1982. The biostratigraphy and correlation of the Merioneth–Tremadoc Series boundary in North Wales. *In* BASSETT, M. G. and DEAN, W. T. (eds.). *The Cambrian–Ordovician boundary; sections, fossil distributions and correlations,* 41–59. National Museum of Wales Geological Series, no. 3, Cardiff.

—— 1983. Trilobites from the Upper Cambrian *Olenus* Zone in central England. *In* BRIGGS, D. E. G. and LANE, P. D. (eds.). Trilobites and other early arthropods: papers in honour of Professor H. B. Whittington, F.R.S. *Spec. Pap. Palaeont.* **30,** 107–139, pls. 14–19.

SALTER, J. W. 1864. A monograph of the British trilobites. *Palaeontogr. Soc.* [*Monogr.*], 1–80, pls. 1–6.

SDZUY, K. 1958. Fossilien aus dem Tremadoc der Montagne Noire. *Senckenberg. leth.* **39** (3/4), 255–288, pls. 1–3.

SHERGOLD, J. H. 1969. Oryctocephalidae (Trilobita: Middle Cambrian) of Australia. *Bull. Bur. Miner. Resour. Aust.* **104,** 1–66, pls. 1–12.

—— 1971*a*. Résumé of data on the base of the Ordovician in northern and central Australia. *In* Colloque ordovicien–silurien, Brest, Septembre 1971. *Mém. Bur. Rech. géol. minièr.* **73,** 391–402.

—— 1971*b*. Late Upper Cambrian trilobites from the Gola Beds, western Queensland. *Bull. Bur. Min. Resour. Aust.* **112,** 1–87, pls. 1–19.

—— 1975. Late Cambrian and early Ordovician trilobites from the Burke River Structural Belt, western Queensland. Ibid. **153** (2 vols.), 1–251, pls. 1–58.

—— 1977. Classification of the trilobite *Pseudagnostus*. *Palaeontology*, **20,** 69–100, pls. 15–16.

—— 1980. Late Cambrian trilobites from the Chatsworth Limestone, western Queensland. *Bull. Bur. Miner. Resour. Aust.* **186,** 1–111, pls. 1–35.

—— 1982. Idamean (Late Cambrian) trilobites, Burke River Structural Belt, western Queensland. Ibid. **187,** 1–69, pls. 1–17.

—— 1988. Review of trilobite biofacies distributions at the Cambrian–Ordovician boundary. *Geol. Mag.* **125,** 363–380.

—— COOPER, R. A., DRUCE, E. C. and WEBBY, B. D. 1982. Synopsis of selected sections at the Cambrian–Ordovician boundary in Australia, New Zealand and Antarctica. *In* BASSETT, M. G. and DEAN, W. T. (eds.). *The Cambrian–Ordovician boundary; sections, fossil distributions and correlations*, 211–227. National Museum of Wales Geological Series, no. 3, Cardiff.

—— JAGO, J., COOPER, R. A. and LAURIE, J. 1985. The Cambrian System in Australia, Antarctica and New Zealand. Correlation charts and explanatory notes. *Int. Union Geol. Sci., Publ.* **19,** 1–85.

SUN YUNCHU. 1924. Contribution to the Cambrian faunas of China. *Palaeont. sin. Ser. B, 1*, Fasc. 4, 1–109, pls. 1–5.

SWINNERTON, H. H. 1915. Suggestions for the revised classification of trilobites. *Geol. Mag.* **2,** 487–496, 538–545.

TAYLOR, M. E. 1976. Indigenous and redeposited trilobites from late Cambrian basinal environments of central Nevada. *J. Paleont.* **50,** 668–700, pls. 1–3.

TROEDSSON, G. T. 1937. On the Cambro-Ordovician faunas of western Qurug-Tagh, eastern Tienshan. *In* Report of the scientific expedition to the north-western provinces of China under the leadership of Dr. Sren Hedin. The Sino-Swedish Expedition Publ. 4. V. Invertebrate Palaeontology, 1. *Palaeont. sin.* NS *B*, **2** (*whole ser. 106*), 1–74, pls. 1–10.

—— 1951. *Hedinaspis*, new name for *Hedinia* Troedsson, *non* Navas. *Geol. För. Stockh. Förh.* **73,** 695.

ULRICH, E. O. and RESSER, C. E. 1930. The Cambrian of the Upper Mississippi Valley, Pt. 1, Trilobita; Dikelocephalinae and Osceolinae. *Bull. Milwaukee publ. Mus.* **12** (1), 1–122, pls. 1–23.

—— —— 1933. The Cambrian of the Upper Mississippi Valley, Pt. 2, Trilobita; Saukiinae. Ibid. **12** (2), 123–306, pls. 24–45.

WALLERIUS, I. D. 1895. *Undersokninga ofver zonen med* Agnostus laevigatus *i Vestergotlands samtliga* Paradoxides-*lager*. Akademisk afhandl., iii, 1–73, pl. 1. Lund.

WANG ZHIHAO. 1984. Late Cambrian and early Ordovician conodonts from north and northeast China with comments on the Cambrian–Ordovician boundary. In *Stratigraphy and palaeontology of systemic boundaries in China. Cambrian–Ordovician boundary*, **2,** 195–258, pls. 1–14. Anhui Science and Technology Publishing House, Hefei.

WHITEHOUSE, F. W. 1936. The Cambrian faunas of northeastern Australia. Part 1—Stratigraphic outline. Part 2—Trilobita (Miomera). *Mem. Qd. Mus.* **11** (1), 59–112, pls. 8–10.

—— 1939. The Cambrian faunas of northeastern Australia. Part 3—The polymerid trilobites (with supplement no. 1). Ibid. **11,** 179–282, pls. 19–25.

WHITTINGTON, H. B. 1965. Trilobites of the Ordovician Table Head Formation, Western Newfoundland. *Bull. Mus. comp. Zool. Harv.* **132** (4), 275–442, pls. 1–68.

WRIGHT, A. J. 1979. Evaluation of a New Zealand Tremadocian trilobite. *Geol. Mag.* **116,** 353–364, pls. 1–2.

—— and COOPER, R. A. 1983. Cambrian–Ordovician boundary at Mount Patriarch, New Zealand. In *Papers for the Symposium on the Cambrian–Ordovician and Ordovician–Silurian boundaries, Nanjing, China, October 1983*, 62–63. Nanjing Institute for Geology and Palaeontology, Nanjing.

XIANG LIWEN and ZHANG TAIRONG. 1984. Tremadocian trilobites from the western part of northern Tianshan, Xinjiang. *Acta palaeont. sin.* **23** (4), 399–409, pls. 1–3. [In Chinese with English summary.]

—— —— 1985. Stratigraphy and trilobite faunas of the Cambrian in the western part of northern Tienshan, Xinjiang. *Ministry of Geol. and Mineral Resour., Geol. Mem. Ser. 2, no. 4*, i–ix, 1–243, pls. 1–52. Geological Publishing House, Beijing. [In Chinese with English summary.]

YANG JIALU. 1978. Middle and Upper Cambrian trilobites of western Hunan and eastern Guizhou. *Prof. Pap. Stratigraphy and Palaeontology*, **4,** 1–82, pls. 1–13. [In Chinese with English summary.]

YIN GONGZHENG and LI SHANJI. 1978. Trilobita. In *Palaeontological Atlas of south-west China. Guizhou Volume, Pt. 1* (*Cambrian–Devonian*), 385–594, pls. 144–192. Geological Publishing House, Beijing. [In Chinese.]

YIN GONGZHENG, GONG LIANZAN, CAI YING and JIAO HUILIANG. 1984. On the Cambrian–Ordovician boundary in Guizhou of China. *Scientific Papers on Geology for International Exchange, vol. 1* (*for 27th Int. Geol. Congr.*), 25–34, pls. 1–2. Geological Publishing Housc, Beijing. [In Chinese with English summary.]

ZHANG TAIRONG. 1981. Trilobita. In *Palaeontological Atlas of Northwestern China, Xinjiang volume, Pt. 1* (*later Proterozoic–Early Palaeozoic*), 134–213, pls. 54–79. Geological Publishing House, Beijing. [In Chinese.]

ZHOU TIANMEI, LIU YIREN, MENG XIANSONG and SUN ZHENHUA. 1977. Trilobita. In *Palaeontological Atlas of Central and Southern China. Vol. 1* (*Early Palaeozoic*), 104–266, pls. 36–81. Geological Publishing House, Beijing. [In Chinese.]

ZHOU ZHIYI, WANG ZHIHAO, ZHANG JUNMING and LIN YAOKUN. 1984. Cambrian–Ordovician boundary sections and the proposed candidates for stratotype in North and Northeast China. In *Stratigraphy and palaeontology of systemic boundaries in China. Cambrian–Ordovician boundary*, **2,** 1–57, pls. 1–3. Anhui Science and Technology Publishing House, Hefei.

ZHU ZHAOLING. 1979. Superfamily Ptychopariacea (Trilobita). *In* ZHU ZHAOLING, LIN HUANLING and ZHANG ZHIHENG. *Palaeontological Atlas Northwest China, Qinghai Volume, Pt. II*, 81–116, pls. 35–45. Nanjing Institute of Geology and Palaeontology and Qinghai Institute of Geology. Geology Publishing House, Beijing. [In Chinese.]

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